Mechanized Maize Production for Enhanced Productivity and Profitability

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Citation: S.D. Bamboriya, S.L. Jat, D. Shreelatha, D.M. Mahala and Sujay Rakshit. Mechanized maize production for enhanced productivity and profitability. IIMR Technical Bulletin 2020/1.Indian Institute of Maize Research, PAU Campus, Ludhiana-141004.

Published in 2020

Published by:
ICAR-Indian Institute of Maize Research
PAU Campus, Ludhiana, Punjab- 141 004 (India)
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सचिव, एवं महानिदेशक
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SECRETARY & DIRECTOR GENERAL

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कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
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FOREWORD

Maize is the largest produced cereal in the world with 1148 mt production with average productivity of 5.9 t/ha, which is the highest. The growth rate of maze is also one among the highest. The crop is spreading very fast to non-traditional areas like peninsular, central and eastern India. This is due to its increased market demand both by multifarious uses as food, feed, fodder and raw material for large number of industrial products besides use in bioethanol production, it is the best suited crop to double farmers' the rice-based cropping system. Convervation agriculture practices have been largely been very successful in maize-based cropping system, with higher system productivity and profitability. However, labour shortage and higher input prices are making agriculture

less remunerative in present context in India. Thus, the use of machineries for crop cultivation is much needed for sustainable production specially the crop like maize that is fast spreading in India.

Maize being widely spaced and dominated by single cross hybrids with uniform ear placement and maturity, it is suitable for mechanized cultivation. Maize cultivation is completely mechanized in the major producing countries like USA and China but unlike rice and whear in India, mechanization in maize cultivation is penetrating at slower pace. It is primarily due to less awareness about applicability of mechanization of maize cultivation an d availability of these machines at farmers' doorsteps. The use of machines for various cultivation practices will help in augmenting the profitability of maize cultivation, reduction of drudgery and improved health of farmers. The mechanization of maize cultivation will help in its faster adoption and enhanced production to meet the future requirement of maize in the country.

I am happy to note that ICAR-Indian Institute of Maize Research, Ludhiana is bringing out a publication on *"Mechanized Maize Production for Enhanced Productivity and Profitability"*, which has the information on the availability of the machineries from seed-to-seed with special reference small holder farmers. I am sure that the compilation will be useful for researchers, farmers and other stakeholders including policy makers for enhaccing maize production and productivity in the country.

Dated: 13th March, 2020
New Delhi

(T. MOHAPATRA)

PREFACE

During the last few decades, the agriculture sector in India has witnessed a drop in the labor availability mainly due to increased job opportunities in service and manufacturing sectors. These declining trends of agricultural labor and raising wages calling for automatic or semi-automatic farm machineries to perform various crop productions tasks.

In India, nearly 80 percent of maize is grown in rain fed region where all the agriculture operations are rain depended and need to be carried out in short time span. Intensive cropping systems particularly in irrigated regions require quick land preparation, seeding and harvesting to incorporate more number of crop in a year. Hence, mechanization is very much in demand in both rain fed and irrigated maize. But, the mechanized maize cultivation is not much popular due to lack of awareness about farm machineries. Hence, to spread awareness about mechanization, different farmers friendly machineries and supportive govt. schemes; a bulletin entitled with "Mechanized maize production for enhanced productivity and profitability" has been written. This bulletin broadly covered need of mechanization in Indian agriculture and particularly for maize crop; important tractor drawn machineries for land preparation, planting, weeding, fertilizer application, harvesting, and post-harvest operations. Animal drawn, manually or power operated machineries that suit the financial status of small and marginal farmers has also been described.

It is hoped that this information will be pretty useful to all the maize growers in the country.

March 2020 Authors
Ludhiana

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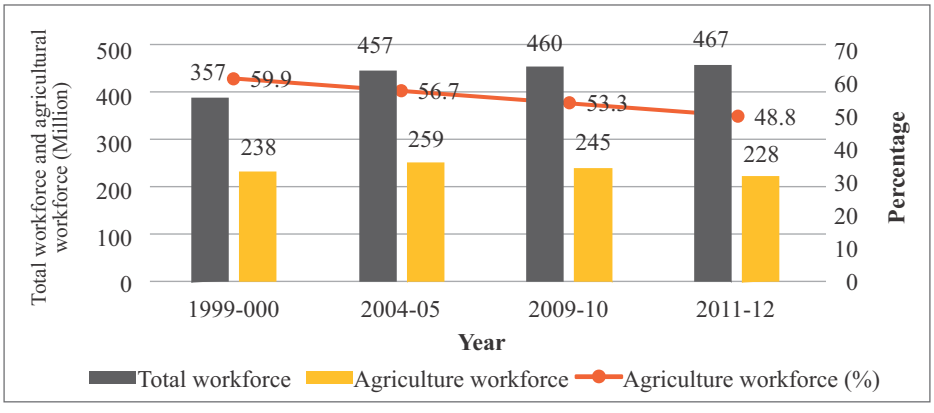
Introduction

Agriculture is the third most important sector of Indian economy with 18 percent share in gross domestic product (GDP). Agriculture is the most important source of livelihood and support nearly 50 percent of Indian population. After the economic reforms of 1990s, spectacular changes were noticed in sector wise share in employment as a result in employment generation in the secondary and tertiary sectors. In 1991, agriculture alone was providing 63 percent employment which dropped to 59.9, 56.7, 53.3 and 48.8 percent in 1999-00, 2004-05, 2009-10 and 2011-12, respectively (Fig.1). The expansion of public works like Mahatma Gandhi National Rural Employment Generation Act (MGNREGA) 2005 and migration of rural population to the cities and abroad in search of employment is other reason for labour shortage in agriculture. As a result share agricultural labour to the total labour force dropped to 43.2% in ten years from 2009 leading to crisis of shortage of labour in agricultural practices. With higher education more labour forces are moving to the industry and service sectors. Agriculture activities being more tiring with lesser social repute there is further possibility for decline in agriculture work force in coming years. Further, agricultural practices being seasonal in nature do not provide regular employment, and on the contrary has peak labour demand during sowing, weeding and harvesting. The seasonal unemployment and the increasing expenditure further force the agriculture workforce to leave agriculture to join other sectors. The scarcity of agricultural laborers at peak period causes delay in key operations like land preparation and sowing, intercultural operations like weeding, nutrient application, irrigation, and harvesting. Further, higher demand for labourers in peak cropping periods enhances the labour wages leading to additional cost of cultivation. All these factors lead to production losses making agriculture production nonviable under certain situations. If the issue of labour scarcity is left unattended it may potentially discourage the farmers, who may leave their land fallow and shift to non-agricultural avenues for livelihood. Farm mechanization is a viable avenue to address many of the issues arising due to shortage of agricultural laborers.



Labour trends in India (Source: NSSO)

Mechanization is defined as application of machine power instead of draught animals or human labour to complete agricultural tasks. Mechanization increases the speed of agricultural practices and saves time and labour in farming operations. It lowers production cost and improves farm income. Mechanization of farm operations can shift agriculture from 'subsistence farming' to 'commercial agriculture'.

Advantages of Mechanization

- Timely and speedy farm operations
- Crop intensification
- Reduced labour drudgery
- Reduced cost of cultivation
- Increase per day and per manpower productivity
- Quality produce
- Improve living standard
- Saving of fuel, labour, natural resources, eco-friendly

Maize is a multifaceted crop grown in varied agro-climatic conditions for food, fodder, feed and industrial purpose globally. Worldwide, maize is cultivated in nearly 185 mha area along with a production of above 1070 mt and average productivity of 5.6 t/ha. In India, this coarse grain is currently being cultivated on 9.6 mha with 28.26 mt production. Among the cereals, maize is the most resource-use efficient and high yielding crop and is extensively used in livestock sector as feed (piggery, poultry, fishery etc.) and fodder. Among field crops maize can best integrated with livestock and poultry components ensuring an integrated farming system, (the core for doubling farmers income. Demand of this crop is rising every year and in future also its demand will be higher due to dietary shift towards non-vegetarian foods.

Why mechanization in maize?

Maize crop suits to mechanization: Maize seeds being relatively bolder as compared to other crops and being wide spaced crop allows tractor to move in the field enabling tractor-based sowing to intercultural operations. Maize cobs are placed well above the ground is amenable to harvesting mechanically. Post-harvest operations like dehusking, shelling, drying etc. are quite labour intensive and amenable to mechanized interventions. Thus, seed to seed mechanization can be successful in maize and much progress in this regard has already been made.

Availability of maize cultivars amenable to mechanization: Predominant cultivars in maize in India till mid 1990s were composites and synthetics. Such cultivars have non-synchronous maturity and uneven ear placement. Both these parameters are not suitable for mechanized operations. Double cross hybrids though higher in productivity than composites and synthetics, have the inherent limitations of uneven maturity and cob placement. On the other hand, single cross hybrids, which have made large scale inroads in the maize cultivation scenario since beginning of this millennium, are uniform in plant type, seed characters, maturity and ear placement. Thus, such cultivars suit best for mechanization from seed to seed.

Maize as commercial crop: Traditionally maize in India used to be consumed as food crop. However, over time maize has become more an industrial crop rather food crop. This is because over 75 % of the maize produced in India is used for industrial purchases (Rakshit et al. 2017) (Fig 2). Being industrial in nature maize can ensure higher remuneration. This has contributed to 1.26 % CAGR of maize area in a span of 51 years between 1966-67 and 2017-18 leading to addition of 3 million ha area under maize cultivation since 2000

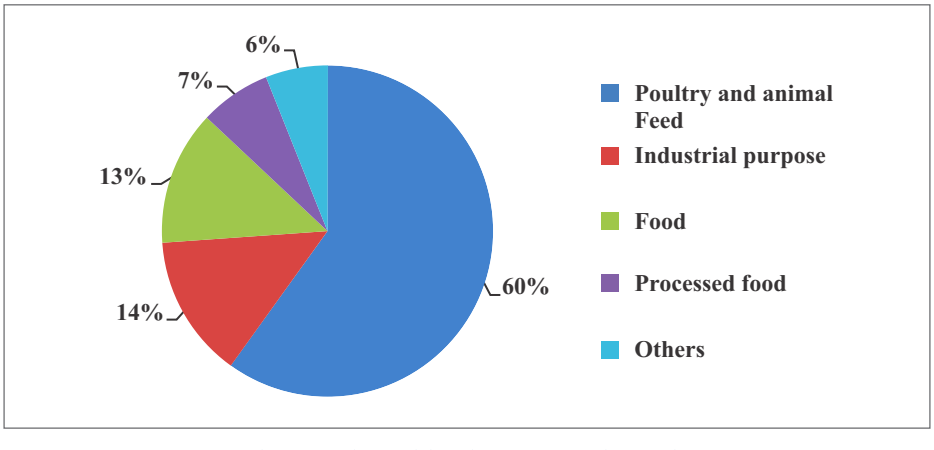


Fig 2. Maize utilization pattern in India

Non-traditional areas under maize cultivation: Maize in India was a kharif crop of north western India in the states of Punjab, Haryana, western Uttar Pradesh. Since mid 1980s there was a gradual shift in maize cultivation, when it made inroads more in peninsular India and losing its major footprint in northwestern India. Currently the peninsular India contributes to over 50 percent of maize production from around 40 percent national maize area. Further, with its continued demand, particularly in poultry and starch industry it is fast spreading to non-traditional areas like West Bengal, rice fallows and coastal belt having mechanized cultivation of other crops, *viz*., rice, wheat etc. To increase farm profitability in such situations mechanized cultivation is the need of the hour.

Maize as rain-fed crop: Over 75 percent of maize in India is (grown as rain-fed crop where operations like sowing, weeding, earthing up etc. are often affected by the rainfall providing little window period to perform these operations. Mechanized cultivation enables conduct of these critical operations on time and reduces drudgery. Further, it enhances farm profitability of rain-fed maize production.

Intensive cropping systems: With increasing demand from agriculture of more produce from less land, intensification of cropping system is the only alternative. Intensive cropping systems particularly in irrigated regions need quick harvesting for timely seeding of successive crop. Here mechanized harvesting as well as land preparation and sowing are very much in demand.

Rain at harvesting: Rain/thunder storms at harvesting can destroy the whole season efforts of farmers. Further, untimely rain during harvesting or while drying maize cobs/grains lead to higher grain moisture leading to risk of aflatoxin. Under this situation mechanized harvesting, dehusking, shelling and drying can very effectively address the issue of aflatoxin, ensuring higher selling price.

Declining agricultural labour in traditional areas: It has already been highlighted previously that availability of agricultural labours is in decreasing trend, which hinders timely farm operations, and make the operations costly. The declining trend of labour in agriculture highlighted the need of farm mechanization in every crop including maize.

Higher labour cost: Labour requirement in different maize growing states ranges between 431 to 753 man hour per ha, which contribute approximately 39-64 percent of total operational cost (Table 1). As large part of cost of cultivation is shared by labour only, hence adoption of mechanization can potentially reduce the requirement of labour and reduce the production cost.

Table 1: State wise labour cost in maize cultivation (Source: Directorate of Economics and Statistics, 2015-16)

State	Total labour requirement (man-h/ha)	Human Labour cost (INR)	Animal Labour cost (INR)	Machinery labour cost (INR)	Operation labour cost (INR)	Human labour cost as % of operational cost
Andhra Pradesh	475.2	18404	3885	5963	42634	43.1
Bihar	520.9	13420	0	3857	29563	45.3
Gujrat	753.3	19788	4288	3390	36171	54.7
Himachal Pradesh	353.47	16352	1770	2452	26759	61.1
Jharkhand	591.0	14374	2423	1699	28803	49.9
Karnataka	517.0	15344	3467	6152	35084	43.7
Madhya Pradesh	431.8	12336	2854	4211	27044	45.6
Maharashtra	678.2	22232	9099	6168	56378	39.4
Odisha	753.2	22929	3935	1993	39671	57.7
Punjab	372.9	15918	337	6629	36738	43.3
Rajasthan	618.3	23147	2416	4330	35922	64.4
Tamil Nadu	724.1	32358	85	8763	64263	50.3
Uttar Pradesh	623.7	15542	1102	4002	27848	55.8

Equipments for mechanization

In order to make maize cultivation more economic mechanization from seed to seed is the best option. The level of mechanization varies from place to place, cropping system to system and size of farming. However, unlike rice and wheat mechanization in maize is less popular and less in practice. However, there are immense potential to introduce mechanization in maize cultivation. Common options for mechanization in maize are detailed in Table 2.

Table 2: Options for mechanization in maize

Operations	Equipment
Tillage and seedbed preparation	MB and disc plough, cultivator, harrow, rotavator, levelers
Sowing/planting	Maize/multi-crop planter, zero till planter, raised bed planter, pneumatic planter, happy seeder, wide bed planter
Fertilizer application	Seed cum ferti-drill and fertilizer broadcaster, tractor operated fertilizer band placements cum earthing up machine
Weeding/inter-cultivation/earthing up	Power weeder, rotary weeder, ridge maker
Irrigation	Engines, pumps, drip set-up
Plant protection	Air assisted boom sprayer, self-propelled high clearance sprayer, Q 5-AC acoustic device for bird protection
Harvesting and threshing	Combine harvester, maize dehusker cum sheller, Maize dryer, Storage structures
Fodder harvesting and further handling	Tractor mounted fodder harvester, chaff cutter, silo pack machine

1) Tillage and seedbed preparation

Tillage is the mechanical opening of soil to prepare a seed bed for proper germination and good growth of plants. Tillage is power intensive operation mainly carried out by tractor or animal drawn plough, cultivator and harrows. Tillage implements are broadly classified as primary and secondary implements. Under primary tillage, cutting and turning of furrow slice is carried out to pulverize the soil. It also helps in burying weeds and weed seeds, and disease propagules in deeper layers. In secondary tillage, harrow/cultivator etc. is used to crush larger clods followed by smoothing/leveling of field. These operations help in good seed germination and uniform crop stand and maturity.

Mould Board (MB) Plough: It is primary tillage equipment which turn the soil, cuts trashes and buries them inside the soil. It is also used for turning and mixing green manure crops/ compost/farmyard manure, lime and other soil amendments into the soil.

Specifications of MB Plough

Dimension (m)	1.77 x 0.88 x 1.09
Weight (kg)	253
Power requirement	45 hp tractor
Approx cost (₹)	30,000

MB plough

Disc Plough: Disc plough is also a primary tillage implement which is used in stony, hard and dry, trashy soils and in soil where scouring is a major problem.

Specifications of Disc Plough	
Disc size (mm)	600-800
Width of cut per disc (mm)	200-300
Weight (kg)	236-376
Adjustable working width (mm)	600-1200
Working depth (mm)	Up to 300
Disc angle (°)	40-45
Tilt angle (°)	15-25
Power requirement	35-50 hp tractor
Approx cost (₹)	30,000

Disc plough

Tyne type Cultivator: Cultivator is secondary tillage implement used for preparation of seedbed. It is also used for intercultural operation/weeding in wider row crops like maize after adjusting tyne spacing.

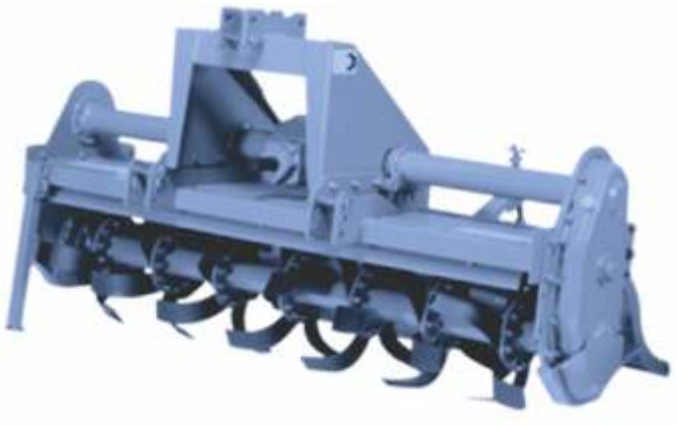
Specifications of Cultivator	
Dimension ((m)	1.96-3.0x0.97-1.56x 1.07-1.35
No of tynes	9-13
Diameter of spring wire (mm)	9.5
Power requirement	35 hp tractor
Approx cost (₹)	25,000-30,000

Tyne type cultivator

Rotavator: Rotavator carries out secondary tillage operations such as harrowing and leveling in single operation. It destroys weeds, incorporates manures/fertilizers and left-over stubble of previous crop, brake down larger clods and pulverizes the soil. It prepares seed bed in one pass saveing draft power, time, labour and cost as compared to conventional tillage. Rotavator can play an important role in intensively cultivated regions where window period for seed bed preparation is very narrow. Continuous use of rotavator may create subsoil compaction just beneath the operational depth, causing accumulations of water under excessive rain. It reduces land preparation cost by ₹ 1000-1500 per ha as compared to traditional method.

Specifications of Rotavator:

Working width of rotavator (m)	1-2
Shape of blade	L shape
Orientation of blade (°)	45-47
Total no of flanges	6-8
No of blades per flange	6
Weight (kg)	280-415
Revolution of rotor shaft (rpm)	210-237
Power requirement	35-50 hp tractor
Field capacity (ha/h)	0.25
Approx cost (₹)	65,000 to 80,000



Rotavator

Laser Land Leveler: Field with undulating topography suffers from uneven crop stand due to uneven seed placement depth and uneven distribution of moisture. It also leads to runoff and erosion, and non-uniform maturity of crops. Uneven field needs higher energy and cost in field preparation. Excess soil moisture at lower elevation causes water logging and leaching, whereas moisture deficit at higher elevation limits water and nutrients uptake. Thus, land leveling is pre-requisite for getting higher resource use-efficiency. Laser land leveler provides a very precise land leveling and results more uniform moisture environment and crop stand. It also saves costly agri-inputs (seed, fertilizer, irrigation etc.). Runoff from field applied/rain water along with applied agro-chemicals also minimized, addressing environmental issues.

Specifications of Laser Land Leveler

Laser Source	< 5mw 635nm
Operating diameter (m)	Above 800
Grade range (%)	–10 to +15 Dual Axes
Grade accuracy (%)	0.015, 3 mm @30 m
Remote control type	Full 2-way communication
Power requirement (hp/KW)	60/45
Approx cost (₹)	3,50,000

Laser land leveler

2) Sowing/planting

Manual method of seed planting, results in un-uniform spacing, low efficiency and serious back ache for the farmer, particularly the rural women force. Mechanical sowing results in better seed placement and also maintains optimum plant population. Some commercially available maize seeding machines are discussed below.

Maize/Multi-Crop Planters: Maize planter release constant quantity of seeds and fertilizer throughout the field. Unlike seed-drill, the planter maintains required plant-to-plant distance, resulting in high yield and saving of costly seeds.

Specifications of Multi Crop Planter

No of rows	3-6
Row to row spacing	24 inch standard and adjustable
Fertilizer metering	Agitator and sliding orifice type
Seed dropping	Rotating disc with cells on its periphery
Approx cost (₹)	40,000-50,000

Multi crop planter

Ridge Planter: Maize is very sensitive water logging. Drought also causes substantial yield loss to the crop. Bed planting saves the crop in extreme water conditions like excess or deficit rainfall. During excess rainfall the furrow act as drainage channel while it stores rain water during low rain events. Ridge planters are commercially available which can do bed making and sowing on the tip of the bed in a single operation. Ridge planting ensure better root development, lesser logging, saving of irrigation water and also cut down operational cost. It can cut down 24 and 90 percent cost and time, respectively when compared with conventional method.

Specifications of Ridge Planter

No of rows	2-5
Row to row spacing	24 inch standard and adjustable
Fertilizer metering	Agitator and sliding orifice type
Seed dropping	Rotating disc with cells on its periphery
Field capacity (ha/day)	3.5

Ridge planter

Zero till planter: In conventional agriculture, one ploughing, 2-3 harrowing followed by planking is done for good seedbed preparation and weed control. These 4-5 runs of tractors and tractor attached heavy tools, press the soil particles affecting soil structure, and create compaction problem which hinder seedling emergence, root penetration, soil aeration and water movement. Further, these conventional tillage operation needs excessive fuel, larger turn around period and labor – enhancing cost of cultivation. Alternative to conventional tillage is no-till planting, under which planting is done in stubble of previous crop without any soil disturbance/tillage operation. This technology reduces capital investment in land preparation and intercultural operations. It is a viable replacement of conventional and tillage-intensive agriculture. This technology is very common in the U.S.A, Canada, Argentina and Australia. In India zero till maize planting has been adopted in coastal Andhra Pradesh in rice-maize system. This technology saves diesel, tractor's working time and labor enabling timely sowing of crops. If zero planting is combined with residue mulching, it modifies hydro-thermal properties and protects the crop during adverse conditions.

Specifications for Zero Till Maize Planter

Seed dropping	Rotating disc with cells on its periphery
Fertilizer metering	Agitator and sliding orifice type
No. of rows	Available in 3-6 rows
Row to row spacing	24 inch standard (maximum) and adjustable
Furrow openers	Inverted 'T' type
Approx cost (₹)	45,000

Zero till planter

Zero-till based permanent raised bed is a resource conservation technology with multifaceted benefits. It is a compatible technology with conservation agriculture as it excludes tillage operations and only need bed reshaping before seeding of succeeding crop. This planting method allows retention of residue and also permits inter cropping and crop-diversification. Reductions in production costs, resource conservation, higher input-use efficiency, and more sustainable soil health are some advantages of permanent bed. Bed planting allows traffic in furrow since tractor tire and furrow maker track in the bottom of furrow. This reduces percolation of water in furrow and diminishes compaction on the bed (plant root-zone). Permanent beds also help in increasing the cropping intensity through reduction in the turnaround time.

Pneumatic Planter: Uniform sowing depth and precise spacing between seed to seed gives uniform germination and also helps in saving of the costly hybrid maize seed using the pneumatic planters in maize. This gives uniform crop establishment and crop stand which increases the maize yield up to 10-20%. These can be kept in custom hiring centers for maize planting.

Specifications of Pneumatic Planter

No. of rows	2,4, 6
Row to row spacing	12 inch minimum and adjustable
Fertilizer metering	Fluted roller
Seed metering	Vertical rotating disc pneumatic seed picking
Sowing depth	Adjustable
Furrow opener	Shovels for sowing in tilled/prepared field
Approx cost (₹)	4-6 lakhs

Pneumatic planter

Happy seeder: Happy seeder consists of a straw management rotor for cutting the previous crop residues and a zero till drill for sowing of next crop. Flail type straight blades are mounted on the straw management rotor which cuts the standing stubbles/loose straw coming in front of the sowing tine and clean each tine twice in one rotation of rotor for proper. The flails pushes the residues as surface much between the seeded rows.

Specifications for Happy Seeder

Seeding metering	Fluted rollers type
Power source	45-50 hp tractor
Field capacity (ha/hr)	0.3-0.4
Cost (₹)	Approximate 1.3 lakh

Happy seeder

Wide Bed planter: This planter is used for broad bed making and planting of maize simultaneously in single operation. It can prepare two raised bed per pass. Two row of maize is sown on tip of each bed.

Specifications for Wide Bed Planter

Seed metering	Fluted Roller / Rotating Disc with cells on its periphery
Fertilizer metering	Agitator and sliding orifice type
Power source	45 hp tractor
Cost (₹)	Approximate 1.3 lakh

Wide Bed planter

3) Gap filling implements

Narrow gaps can be compensated by more tillers production in the case of tillering crops (cereals except maize). Maize being a non-tillering crop needs optimum plant population for realization of good yield. So, gap filling is an essential practice for maize crop and should be done immediately after seedling emergence.

Naveen Dibbler: Naveen dibbler is economic and user-friendly tool for gap filling operation. It avoids bending posture as against traditional dibbler. For its operation, the dibbler is held in both hands and jaws are pushed into the soil to the desired depth at an angle of 20° with vertical. The dibbler is given a jerk at the handle in the forward direction, which rotates the roller in seed hopper and releases one or two seeds depending upon the size of cell. At this moment the jaws also open and allow the seed to fall in the cavity created by the jaws. Its capacity is 300 holes or planting per hour.

Specifications for Naveen Dibbler	
Dimension (m)	0.280 x 0.26 x 1.06
Weight (kg)	2.5-4
Source of power	One person
Seeding metering	Cell type wooden roller (single groove)
Penetration	Spring actuated jaws for penetration
Depth of placement (mm)	35
Field capacity (ha/day)	0.25

4) Fertilizer application

Tractor Mounted Fertilizer Broadcaster: This equipment is used for uniform broadcasting of granular fertilizer. The broadcaster, mainly consists of a hopper and a spinning disc. The fertilizer from the hopper is made to fall on the spinning disc rotating at high speed, which in turn uniformly spreads the fertilizer.

Specifications for Fertilizer Broadcaster	
Type	Tractor mounted
Hopper capacity	500 liter fertilizer
Fertilizer spreading mechanism	High speed rotating disc
Hitching	3 point linkage
Fertilizer spreading width	20-30 feet
Field capacity (ha/h)	2.5

Fertilizer broadcaster

Tractor operated three row fertilizer band placements cum earthing up machine: This machine can perform three tasks in single operation, which are as follows:

- Placement of fertilizer (60 to 250 kg/ha) along the row (50 to 100 mm away from the plant),
- Earthing up (can cover 10 cm height of stem) and
- Cutting of weeds

This machine can save considerable amount of fertilizer, time and labour over traditional method. The field capacity of machine is 0.56 ha/h. The approximate cost of the machine is ₹ 50,000.

5) Weeding

Weeds are the undesirable plants and compete for resources like water, nutrients, sunlight, space etc. with the cropped plants. They reduce crop yield and quality to a great extent. Congenial climatic conditions encourage more weed growth in the widely spaced crop like maize and cause yield reduction to the tune of 29 to 70 percent if maize crop is not kept free during the critical period. Weeding operation is generally carried out with manually operated hand tool known as *khurpi*. Upright bending posture during weeding induces back pain in workers. Further, manual weeding is time consuming and requires considerable number of laborers which is generally scarce during peak period. Due to labour scarcity, higher labour cost and drudgery, manual weeding is becoming lesser popular. Further during rains in kharif season manual weeding gets delayed considerably, contributing to considerable yield loss. Mechanical methods of weed control can complete the task in very short time, are viable alternative of the manual weeding especially in organic cultivation. Mechanical weeding implements can destroy weeds by burying/ cutting/uprooting.

Cultivator: Cultivators are popular agricultural implements used for intercultural operations/weeding after adjusting tine spacing. Mechanical weed control using tractor mounted

implements can only be done during the early crop stages because limited tractor and cultivator ground clearance damage the crop foliage at later growth stages. Working depth should be shallow to prevent plant roots damage.

Self-propelled power weeder: It is a diesel engine operated weeder with 50 cm operational width. It can cover 1-1.2 ha area per day. The weeder is suitable for inter-culture operations and inter-row weeding of maize and other crops like tapioca, cotton, sugarcane, tomato and pulses having row spacing more than 45 cm. Its tines can be adjusted to suit the row to row spacing of the crop and depth of operation. Attachments like sweep blades, ridger and trailer can also be attached with the machine.

Specifications for Power Weeder	
Working width (mm)	350-500
Power source	3 hp engine
Field capacity (ha/h)	Weeding- 0.06 Earthing up-0.14
Approx cost (₹)	80,000

Tractor mounted 3-row rotary weeder: With single pass the weeder can clean three consecutive rows (1600 mm width) at a time. The rotary type weeder damages the weed root and removes them from the soil. Additionally, this creates dust mulch for conservation of soil moisture and also aerates the soil. It is suitable for the wide row crops (45-90 cm) like maize and cotton, in which the tractor can run in the rows without disturbing the crop zone. The width of inter-row rotary weeder can be change according to the crop row spacing. To achieve efficient weeding with least crop damage, the crop height should be less than 55 cm.

Specifications for Rotary Weeder	
Type	Rotary type
No. of rotary weeder units	3
No. of blades per flange	4
Row spacing (mm)	675-1165 (adjustable)
Field capacity (ha/h)	0.24
Operation efficiency (%)	83-87
Approx cost (₹)	60,000

Rotary weeder

6) Irrigation

Utilization of electricity/diesel operated water lifting pumps reduces labour and time required to lift water and cover bigger crop area. Although, maize in India is basically a rain-fed crop, in some ecologies, particularly during rabi season it is grown with irrigation. Flooding or furrow method is more common for maize cultivation. These surface methods of irrigation need precise land leveling and water-guidance channel for uniform water distribution. These conventional irrigation methods are labor-intensive especially for irrigation channel construction, maintenance and operation. Such systems are also less efficient in water economy. Drip irrigation does not need leveling, channel formation and channel maintenance. Farmers do not have to hire labour for irrigation as they can operate the drip irrigation system by push of a switch. Simultaneous application of water and other inputs like fertilizer, insecticide and herbicide through drip lines are also possible which save labour and cost of application of agri-inputs. Sprinkler irrigation is possible till 10-12 leaves stage of the crop. This also can save water but involves some amount of labour to fix and move pipes and sprinklers.

Maize with drip irrigation

7) Plant protection

Manually-operated knap-sack sprayer involves drudgery and needs more time to cover the field. Use of mechanical sprayers ensures timely plant protection and efficient use of agro-chemicals.

Air assisted horizontal Sleeve Boom Sprayer: Boom sprayer can spray larger area with negligible time. It works well in wide space row crops having enough row to row spacing for mobility of tractor. Crop planting needs to be done in rows keeping in view track width of the tractor. The clearance provided in the boom sprayer mounting frame was not sufficient for crop more than 45 cm height so these sprayers are suitable for pre-emergence and early post emergence application of agro-chemicals. It can cover 1.12-1.25 area in an hour.

Specifications of Boom Sprayer	
Dimension (m)	6.34x1.29x1.57
Tank capacity (liters)	400
Weight (kg)	150
Adjusted range of boom height (m)	0.3-1.26
Spacing between two nozzles (mm)	460
Spray swath (m)	10.2
Power requirement	35 hp tractor
Field capacity (ha/day)	8 (with 14 nozzles)
Approx cost (₹)	50,000

Self Propelled high clearance sprayer

Q-5AC acoustic device for Bird Management: Nearly ten bird species feed and damage the maize cobs. The yield loss due to bird feeding is huge and ranges between 10 to 40 percent in the case of maize crop. Hence, automatic electrical sound producing device is designed by All India Network Project on Agricultural Ornithology. The acoustic device keeps away birds from fields by producing recorded sounds. The device produces natural sound of bird predators and alarm call of pest birds. Thus, the pest birds avoid the broadcast area. It is a weather resistant equipment and it needs to be put one foot above crop canopy on a pole. Its approximate cost is ₹ 9,000 and one device can protect 4 acres of farm from bird damage.

8) Harvesting

Timely harvesting of a crop is vital to achieve better quality and higher yield especially under bad weather conditions. The traditional practice of maize harvesting consists of stubble cutting with sickles followed by manual picking of mature cobs and requires 80-110 man-h/ha. This traditional method of harvesting is labour intensive, time consuming and also involves lot of drudgery. Mechanized harvesting using combine harvester reduces cost and ensure timely harvesting.

Shelf propelled Maize Combine Harvester: It is used for direct harvesting and threshing of maize crop. It has specially designed cutter bar for maize. It has a gathering unit to guide the stalks into the machine and snapping rolls to remove the ears from the stalks. It can be used for harvesting other cereal crops in one operation by changing the header. It can harvest one ha in an hour.

Specifications of Maize Combine Harvester	
Cutter bar width (m)	3.65
Cutting height (mm)	100-1000
No. of straw walker	5/7
Area of straw walker (m2)	0.89
Row spacing (mm)	460-685
Type of threshing bar	Rasp bar
Power requirement	75-110 hp
Working capacity (ha/h)	1
Approx Cost (₹)	12-14 lakh

Self propelled high clearance sprayer

9) Threshing

Separation of grains from ear/cob is known as threshing. In case of maize, the word shelling is used instead of threshing. Shelling is the most important post-harvest operation in maize.

Maize Dehusker Sheller: This dual-purpose machine is suitable for simultaneous removal of the cobs sheath along with separation of maize kernels from the cobs. It can save 95% shelling time and 60 % shelling cost as compared to traditional method.

Specification of Maize Dehusker Sheller

Type of threshing drum	Spike tooth
Type of blower	axial flow
Moisture content of cob (%)	12-18
Cylinder speed (rpm)	670-750
Threshing capacity (q/h)	15-20
Threshing efficiency (%)	98-99.5
Cleaning efficiency (%)	90-95
Power requirement	26.25 kw
Approx cost (₹)	60,000

Maize dehusker and sheller

10) Maize drying

During harvesting of maize, grain moisture content is quite high (~30-35 %). Due to higher moisture content farmers cannot get good price of their produce. Beside this, storage at high grain moisture creates problems of fungal infection and can cause heating and loss of germination. Hence, after crop harvesting, produce drying is very much essential.

Mobile Batch Dryer: It is PTO or electricity driven, portable and long lasting dryer. It can dry any

type of grain and do not need pre-cleaning of grains. It is free of the risk of blockages or hot spots. Its drying rate ranges between 2-10 t/h depending on crop type, grain moisture content etc.

Mobile batch dryer

11) Grain storage

Large scale kharif maize harvesting during October-November months, result in market price drop. Hence, to fetch better price, farmers generally store the produce for higher profitability. But, the higher atmospheric humidity, cloudy weather and higher grain moisture content leads to fungal infection and physical deterioration of maize grain. Hence, proper drying followed by moisture proof storage are very much needed for long term storage of maize grains.

Pusa Bin: This storage structure is rectangular in shape and constructed of bricks and earth. It is modification of ordinary mud storage structure. To make this silo moisture proof, a plastic film (700 gauge) is used all around (inner side) of bin. It can store up to 3 tonnes of well dried grains for longer period with minimum loss.

Metal Bin: The metal bin is moisture proof storage structure and made of steel or Aluminium. The bin is durable and also commercially available. The capacity ranges from 1 to 10 tonnes.

Pusa Cubicle: This is further modification of Pusa bin. It has higher storage capacity. It is a room like structure with the dimension of 3.95 3.15 2.60 m with nearly 30 m3 total storage capacity. It is made up of bricks, concrete and polythene sheets.

12) Fodder harvesting and further handling

Maize is considerably being used as fodder. Green fodder harvesting and further handling by traditional method is a labour intensive operation. It needs nearly 40 man-days per ha for manual harvesting, stacking, loading in trolley and unloading etc.

Now a day, machines are commercially available which can perform three tasks in single operations i.e. harvesting, chopping and loading into trolley in a very cost-effective way.

Table 3: Fodder harvester for maize (Source: Sahay et al, 2016)

Specifications	Hand held range fodder harvester	Tractor operated shear plate fodder harvester-chaffer-loader	Tractor operated flail fodder harvester-chaffer-loader
Tasks	Harvesting	Harvesting, chopping, and loading	Harvesting, chopping, and loading
Capacity	0.15 ha/h	16 q/h	70 q/h
Suitability	Suitable for small dairy farms	Suitable for medium farm where less than 1 ha fodder harvesting per day is needed	Suitable for large dairy farm which need 2 ha fodder harvesting every day
Width of operation	--	600 mm	1800 mm

Tractor mounted Fodder Harvester: This machine is suitable for fodder crops like bajra, sorghum, maize, berseem and oats with up to 80 plant/m2 and 100-282 cm plant height. It can harvest 1.12-1.26 m width in single pass and can fill one trailer with chopped fodder in just 22 min. It is also capable of harvesting over mature and lodged crop. The cost of harvesting one trailer of fodder ranges between ₹ 59-104. The field capacity is 0.2 ha/h. and cost of operation ₹ 1114 /ha. One tractor driver and one other person are needed during the whole operation. It can save 90 percent labour and 75 percent operation cost. The harvested fodder can be used as direct feeding or silage making.

Chaff Cutter: The chaff cutter is needed to cut green plants into small pieces for efficient feeding. For this purpose, manually, electrical and tractor operated chaff cutters are available.

a) Manual chaff cutter

b) Electrical chaff cutter

Table 4: Comparison between different chaff cutters

Specification	Manually operated chaff cutter	Electric operated chaff cutter	Tractor mounted movable chaff cutter
Power source	Manual, two persons	1-10 kW electric motor	Tractor
Mobility		Fodder is brought to chaffing yard where machine is installed to perform the operation. This consumes labour and time	The chaff cutter is taken to the place where material is heaped. This save labour and time
Capacity	1.8 to 2.0 q/h	25- 100 q/h	52.8 – 76.3 q/h
Operation cost	₹ 8/q	--	₹ 7/q
Suitability	Small dairy farm	Medium dairy farm	Large dairy farm having more than 20 animals
Cost (INR)	10,000	50,000	

Silo Pack Machine: The machine can cut and crash the green fodder, load in the 50 kg air tight plastic bag and compress it. After this process, the bag can be sealed with thread and can be stored in open place for ensiling (process of silage making). These 50 kg capacity bags are easy to handle and transport. It is having capacity to pack 30 bags/h.

Specifications of Silo Pack Machine

Type	2 core horizontal press
Power	5 hp
Capacity (q/h)	10-15
Portable	Portable on two wheels

Silo pack machine

User friendly tools for small and marginal farmers

1) Field preparation:

Animal drawn Blade Harrow: This animal drawn tillage implement cut thin slice of soil and also remove weeds. The V shape blades provide speedier and uniform operations as compared to straight blade.

Specifications for Animal drawn Blade Harrow	
Cutting width (mm)	500-600
Shape of blade	V shape or straight
Weight (kg)	25-30
Capacity (ha/day)	0.5-0.6

Animal Drawn Cultivator: This cultivator is suitable for shallow ploughing, intercultural operations and weeding. Its working width is adjustable and can be changed by varying the spacing between the tines. During tillage operations tines dig into the soil and cut a small furrow slice. During intercultural operation, the tines uproot weeds and create dust mulch. A seeding attachment can also be provided on the frame.

Specifications of Animal Drawn Cultivator	
Weight (kg)	20
No. of tines	3-5
Shovel type	Reversible
Working width	Adjustable
Capacity (ha/day)	0.6-0.7

Animal Drawn Ridger: Ridger is used to prepare irrigation channels and ridge before planting or for earthing up in standing crop. It has two mould board plough one for turning the soil in left and other in right.

Specifications of Animal Drawn Ridge Plough	
Weight (kg)	25
Wingh width (mm)	690
Length (mm)	780

2) Sowing operations

Naveen Dibbler: Already described earlier, it is a manually operated dibbler suitable for sowing and gap filling of maize, pea, soybean, sorghum etc. in small plots or hilly terrains. It is women friendly equipment as dibbling operation is carried out in standing posture and discomfort due to the bending is avoided. Its capacity is 0.25 ha/day. It saves 35 % labour and 36 % operation cost compared to conventional method of hand dibbling. Its purchasing costs is ₹ 200 only.

Rotary Dibbler: It is a manually operated device for dibbling of medium and bold size seeds such as maize, soybean, sorghum, pigeon pea and bengal gram in well prepared seedbed. The plant to plant distance depends upon size of the polygon plate.

Specifications of Rotary Dibbler	
Weight (kg)	21.5
Seed metering	Cell type wooden roller, six cells
Seed placement device	Jaw type
Jaw spacing (mm)	225
Field capacity (ha/day)	0.6-1.0
Approx cost (₹)	2300

One row Seed Cum Fertilizer Drill: It is a single row machine suitable for sowing wheat, soybean, green gram, pigeon pea, maize etc. It is operated by two persons. It ensures uniform distribution of seeds and fertilizer and mainly suitable for black soils and hilly regions.

Specifications of One row Seed Cum Fertilizer Drill	
Dimension (m)	1.8 x 0.6 x 0.95
Weight (kg)	17
Seed metering	Fluted roller
Furrow opener	Shoe type
Operating speed (km/h)	2.6
Jaw spacing (mm)	225
Field capacity (ha/h)	0.05 (at 45 cm raw spacing)
Field efficiency (%)	85-90

Metallic Tip Dibbler: It is used for dibbling maize and other bold seeded crops on hill slopes. It gives better result as compared to local dibbling stick. It can place seed up to 7 cm depth against 3-4 cm for non-metallic dibbler. Its field capacity is about 0.10 ha/day at 40 cm row-to-row spacing. The cost of the dibbler is ₹ 70 only.

Animal Drawn Multi-Crop Planter: This animal drawn planter can plant 3 rows simultaneously. It is also suitable for sowing of inter crop as different crop seed can be fill in different boxes. One can adjust row spacing between 25 and 45 cm.

Specifications of Animal Drawn Multi-Crop Planter

Seed metering	Inclined plate type
Furrow opener	Shoe type
Fertilizer metering	Fluted roller type
No. of rows	3
Field capacity (ha/h)	0.16-0.2
Approx cost (₹)	15,000

Zero Till one row Planter: This is a manually operated single row push type planter. It is suitable for no-till planting of maize in previous crop stubble.

Zero till single row planter

3) Hilling/earthing up

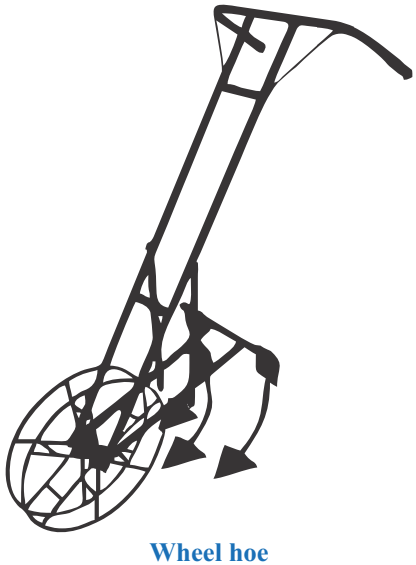
Hand Ridger: A manually operated hand ridger can form ridge and furrow very easily. The equipment is operated by two workers, one for pulling and another for pushing and guiding. It is women friendly and light weighted tool and also avoids the bending posture during the operation. Its field capacity is 330 m^2/h.

4) Weeding

Wheel Hoe: It is a manually operated long handle tool used to uproot and cut the weeds in row seeded upland crops. The frame has got a provision to accommodate different types of soil tools like straight/reversible/v-shape blades, sweeps, tine cultivator, spike harrow (rake) etc. The handle assembly has a provision to adjust the height of the handle to suit the operator. It covers 0.10 ha/day.

Specifications for Wheel Hoe

Dimensions (m)	1.4-1.5 x 0.45 - 0.5 x 0.8-1
No. of tines	3
Wheel diameter (mm)	200-600
Working depth (mm)	Up to 60
Weight (kg)	4-12
Approx cost (₹)	1200



Wheel hoe

Animal drawn Blade Harrow: Blade harrow is cheaper and widely used implement for intercultural operation. The sharp metal blades (length-40-60 cm) are attached to wooden frame. It is multi-purpose implement used for weeding and digging out potato and groundnut. It loosens the soil and cut roots of weeds without disturbing/turning the soil. Hence, it reduce soil moisture loss and highly suitable for inter-culture operation in semi-arid regions.

Specifications of Animal drawn Blade Harrow	Type	
	One row	Two row
No. of row weeded per pass	1	1
Weight (kg)	12	18.5
Working width (mm)	300	700
Cutting width of blade (mm)	350	350
Shape of blade	Concave	Concave
Capacity (ha/day)	0.5-0.6	0.8-1

5) Harvesting

Naveen (serrated) Sickle: It is having steel blade with special serration and special handle that make operation easy and comfortable. The wooden handle has a bend at the rear for better grip and to avoid injury during operation. It is very cost effective and farmer friendly tool. It saves labour, time and cost of operation as compared to local sickle. The field capacity of the sickle is 0.018 ha/ha and labour requirement is 80 man-h/ha. It is very cheaper and available @ ₹ 60.

6) Shelling

Tubular Maize Sheller: It is hand operated sheller suitable for separating of maize grains from individual dry and dehusked cobs. It is tubular in shape and posses four tapered fins to remove maize grain from dehusked cobs. Shelling is done by little forward and backward twist of sheller. The capacity of the sheller is 15-20 kg/h as against 10-12 kg/h in traditional method. It costs is only ₹ 60, hence easily affordable by resource poor farmers.

Tubular maize sheller

Specifications of Tubular Maize Sheller	
Dimension (mm)	72 x 63 x 58
Weight (kg)	0.2
Capacity (kg/h)	15-20
Approx Cost (₹)	25

Pedal operated Maize Sheller: The hand shelling of maize is laborious cum time consuming. Pedal operated sheller works without electrical power source and does not need extra skills. It is cheaper and easily affordable equipment by small farmers.

Specifications of Pedal operated Maize Sheller	
Weight (kg)	55
Power source	Manual
Shelling cylinder	bar spike tooth type
Power transmission	Fly wheel
Capacity (kg/h)	70

Pedal operated maize sheller

7) Two-wheeled tractor mounted equipments

Two wheeled tractor with different attachments can fulfill multiple field tasks like land preparation, planting, harvesting, and transportation. The tractor is designed for small farmers who cannot afford to costly normal size tractor. The two-wheeled tractor having single axil with power take off shaft with which we can attach a no. of implements like plough, harrow, roto-tiller, planter, ridger, harvester etc and can perform agricultural operation in cost effective manner with lesser time. It is small and easily portable and also suitable for uneven topography. It is a multipurpose tool which perform many tasks like field ploughing & leveling, sowing, intercultivation, ridge making, irrigation water lifting, spraying, pulling a trailer etc hence will be useful in mechanization in developing nations having small and marginal land holdings. Its cost is approx ₹1 lakhs. Following special implements can be attached with the two-wheeled tractor through PTO.

Table 5: Attachment for 2 wheel tractor

Implement	Description
Powered rotary plough	It is suitable for breaking up the hardest ground. This powered plough has rotating blades ((plough shares) which dig through the earth and discharge it to the side. In a single pass the rotary plough will create an area of worked soil, leaving the ground ready for planting.
Power harrow	It dig and level the ground simultaneously, leaving a fine, level surface ready for seeding. Available in either 60/75 cm working widths with vertical counter-rotating tines to level and prepare surfaces for seeding.

Implement	Description
Rotavator	It is a fantastic tool which produce a fine tilth in even the most demanding conditions.
Reversible plough	It is fully adjustable for depth and angle and is the ideal tool for "wintering over" once the crop has been lifted.
Tined cultivator	The tined cultivator, is ideal for inter-row weeding and for breaking up previously ploughed ground.
Power tiller drawn cup feed seeder	This implement is suitable for seeding groundnut, maize, sorghum and pulses etc. It can plant four row of crop with 25 – 60 cm (adjustable) row spacing . Its field capacity is 0.2ha/h. Approx cost of the unit is ₹ 20,000.
Power tiller operated boom sprayer	Good for row crop spraying. The boom sprayer attachment consists of two aluminum hollow sections (50 25 mm) of 4 m length with 16 numbers of nozzles at 450 mm spacing. Its capacity is 1 ha/h. Approx cost of the unit is ₹ 35,000.
Adjustable ridger	The adjustable ridger is ideal for "earthing up" and for creating ridges and furrows in previously cultivated ground.
Trailed ridger	The trailed ridger is ideal for “earthing up” and for creating ridges and furrows from 10 - 23 cm deep.
Power tiller operated axial flow pump	Used to lift water from open water sources. Its capacity is 2500 litres per minute at 3.0 m head. Approx cost of the unit is Rs. 16,000.
The dozer blade	It is ideal for moving and dozing gravel, sand, earth, and other small debris, and for leveling ground.
Wheel barrow	It is used for transporting load from one place to another.



Fig. (a)Two wheel tractor, (b) Powered rotary plough, (c) Tined cultivator

Custom Hiring Centres

Labour shortage and higher labour wages making agriculture less remunerative. Adoption of mechanization can ensure higher productivity and profitability in crops like maize. Besides this, mechanization also provides job opportunities to rural youth, facilitates in cultivation cost reduction and helps in efficient use of costly inputs. In India, large no. of machineries are available for automation/semi-automation of agricultural operations. But most of the heavy machineries are unaffordable by resource poor small and marginal farmers. Hence, Indian government through various schemes supporting purchase of equipment by individual farmers or creation of Custom Hiring Centres (CHCs). Agri-preneurs can purchase major implements such as tractors and tractor mounted implements like ploughs, harrow, cultivator, rotovator, land leveler, seed drills, bed planter, sprayers, multi crop oower thresher, combine harvester, repairing tools etc. to provides these implements on rental basis to needed farmers. The farm implements rental service can reduce the problem of labour shortage and improve farm mechanization & crop yield. Progressive farmers, rural unemployed youth and agri graduates can set up the CHCs.The CHCs shall have to be located in a place where by most of the small land holdings are located within a radius of 5 to 7 kms. This will reduce the transport cost and time of transport of agricultural machinery.

To increase the reach of farm mechanization to small and marginal farmers government of India running a scheme "Sub-Mission on Agricultural Mechanization (SMAM)" under Department of Agriculture Cooperation with 60-40 centre-state sponsorship. The main aim of the scheme is to make machineries affordable by poor farmer through subsidy and to promote 'Custom Hiring Centres' to hire out agricultural machinery and implements on nominal charge to the needy farmers.

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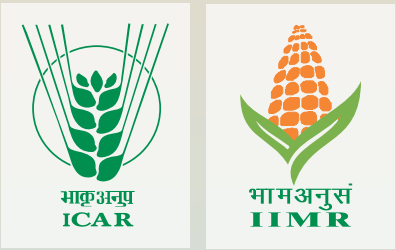

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PUBLISHED BY

Director, ICAR- Indian Institute of Maize Research

Design & Printed at ***Azad Offset Printers,*** *Chd.*
Mob. 9814011543, 9814111543, 9914111543