AGRICULTURAL MACHINERY USED IN MODERN INDIA (1950-2010)

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Abstract: Agriculture is main occupation of Indian farmers from Ancient time. There are so many works in agricultural production such as ploughing, sowing, harvesting and threshing etc. and to complete these work farmers needed equipments. With the help of these implements agricultural works are become easy. In this paper I have described different types of agricultural implements which are used in Modern India for daily agricultural works.

Keywords: Combine harvester, Laser Leveler, Planter, Power Tiller, Sprayer etc.

Introduction: It was from the latter half of the nineteenth century that the mechanization of agricultural production took major leap, pushed by both the government and private players. This was very closely connected with the rapid and effective industrial developments in Western Europe and U.S.A. A strong demand for labour in other industries resulted in the progressive withdrawing of labour from working in the farms, which led to a shortage of farm workers. Forcing the agricultural workers wages shooting up, this proved to be the major incentive for bringing in more machines for agricultural production.[1]

It is also significant to note that maximum progress in mechanization in early twentieth century had happened in those countries where farms were of moderate size and were already consolidated in the nineteenth century. The Western European agriculture since 1850's had also become progressively more intensive, not only by shifting production to higher-value products, but by increasing inputs of fertilizer, by using better seeds and cultivating the land more efficiently with improved implements.[2]

First World War, further provided incentives for another great surge in agricultural production. Labour became not only very expensive, but unobtainable as they were drafted in the military. To increase the output per man on the farm, there was a very strong move towards mechanization. By the end of the Second World War there were 2.5 million large tractors on the farms. Large tractor for cultivation followed by a grain-drill, thus preparing the land and planting the crop in one operation, required only minutes for one operator for each acre. Harvesting and threshing with the large combines available could be done at the rate of ten acres per hour or six minutes per acre. The total human labour inputs for land preparation, seeding, harvesting and threshing one acre of wheat became less than one hour.[3]

With the rapid rise of mechanization in the late nineteenth and twentieth century, particularly in the form of the tractors and later the combine harvesters, farming tasks could be done with a speed and on a scale previously impossible. These advances, helped by science-driven innovations in methods and resources, led to efficient, mechanized modern farms in the United States, Argentina, Israel and Germany. The development of rail and highway networks and the increasing use of container shipping and refrigeration in developed nations had also been essential to the growth of mechanized agriculture.

The Indian labour story was different from Western countries, there was no shortage of farm hands, working on the field continued to be the main occupation of the majority and as most farmers continued to employ age old methods of farming they needed cheap and readily available labour. To make things easier for farmers the Indian government abolished both the land revenue and the ownership of land. Even then, the scenario was bleak, the cultivator was mostly in debt, there was over dependence on good timely rainfall, very little knowledge had percolated down to the ground about the latest innovations in the field. There was shortage of essentials like fertiliser and pesticides. The Indian cultivators were lagging far behind their Western counter parts, majority of our farmers still continued farming in the most archival ways.

Stagnation had crept into the agricultural sector by the end of 1950s leading to a shortage in supply of food grains and also the much needed raw materials for sustenance of the process of industrialization. The absence of agricultural surplus created a situation where in the limited foreign exchange reserves had to be utilized to import food grains to avoid a famine-like situation. The situation prepared the ground for the intervention of US experts from the Ford Foundation, who were invited by the government and submitted a report in 1959. It was on the basis of their recommendations that the Intensive Agricultural District Programme (IADP) was adopted as a strategy to concentrate the development effort on certain select irrigated districts and specific crops with the objective of enhancing food production.[4]
There are the following newly developed machines which are used in India for agricultural purposes.

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[1] B.S. Pathak, 'Mechanization of Agriculture in India', A.S. Atwal, *New Concepts in Agricultural Education in India,* Punjab Agricultural University Press, Ludhiana, 1969, 556.

[2] D.B., Gridg, *The Agricultural Systems of the world An Evolutionary Approach*, Cambridge University Press, Cambridge, 1974, 172.

[3]M.S.Randhawa, *Green Revolution: A Case Study of Punjab*, Vikas Publishing House, New Delhi, 1974, 11-13.

[4] Y.V.Krishna Rao, *Agrarian Scenario: 1947-1997,* Navkamataka Publications, Bangalore, 1999, 18 and G.S.Bhalla, 'Agricultural Development in India Since Independence' in R.A.Choudhury, Shama Gamkhar, Aurobindo Ghose(Ed), *The Indian Economy and its Performance Since Independence,* OUP, Delhi, 1990, 195.

Tractor: Tractors have become a much better source of power. Not only does it plough and cultivate; it sows and reaps, mows and hauls. Tractors are a major industry and significant contributor to agriculture output gains. War surplus tractors and bulldozers were imported for land reclamation and cultivation in mid-1940s. In 1947 central and state tractor organisations were set up to develop and promote the supply and use of tractors in agriculture and up to 1960, the demand was met entirely through imports.

The first Indian Institute of Technology (IIT) at Kharagpur was established in 1952 and its agricultural engineering program was successful. During this period tractors were not manufactured in India and all tractors were imported. The number of tractors in use grew from 8 000 in 1950 to 20 000 in 1955 and 37 000 units by 1960. These were used mainly on larger government and private farms. Up to 1960, most farm operations and transport work was done using draught animals.[5]

Demand of tractors in the country was met through import until 1961 when Eicher Tractors Ltd. and Tractors and Farm Equipment Ltd started manufacturing tractors with foreign collaborations. The local tractor production started in 1961-62 with 880 tractors. To meet the additional demand, import continued up to 1977. Meanwhile many other industries started manufacturing tractors with foreign collaboration such as Gujarat Tractors Ltd (1963), Escorts Ltd (1966), International Tractors (India) Ltd. (1966) and Hindustan Machine Tools Ltd (1977). Punjab Tractors Ltd. started their production with indigenous technology in 1974. Many more companies started manufacturing tractors indigenously with foreign collaboration.[6] The major international manufacturers have now established plants in India for example John Deere and New Holland. Due to mergers, Mahindra and Mahindra (M&M) and Tractors and Farm Equipment (TAFE) have become huge conglomerates with international operations.[7]

Table 1 Tractor Sale by various Manufacturers

Manufacturers	2004-05	2008-09
M&M	65394	133514
Tractor and Farm Groups	52851	76609
Escorts	31696	43286
John Deere	16020	78938
Sonalika	26364	29520
Punjab Tractors	30330	*
NHI	10445	21002
HMT	7032	4109
Force motors	4016	1065
MGTL	2448	*
VST	935	2329
Total	247531	342836

Note: *merge with Mahindra and Mahindra (M&M)
Source: Mechanization for Rural Development: A Review of Patterns and Progress from around the World, Food and Agricultural Organization, Integrated Crop Management United Nation, Rome, Volume-20, 2013,114.
Report of the working group on Crop Husbandry, Agricultural Inputs, Demand and Supply Projections and Agricultural Statistics for the Twelfth Five Year Plan (2012-2017), Planning Commission, Government of India, 2011, 63.

Power Tiller: The manufacture of power tillers started in 1961 with Japanese collaborations. At one time 12 models of power tillers were licensed to be manufactured. The manufacturers started offering these to farmers in various states covering upland and wetland farming conditions. The power tiller models being manufactured and also those being imported from China and being marketed for wetland, stationary and haulage work are being well received by the farmers. The 7 available models have a drawbar power between 5.3 kilowatt to 10.7 kilowatt. Their production and sale has also increased to about 16000 units annually.[8] In 1965-66 the power tillers production was 329 which rose 15665 in 2003-04.[9]

VST Tillers was set up in 1965 in Bangalore with collaboration of Mitsubishi Agricultural Machinery of Japan.[10] The market for power tillers in India is mainly concentrated in the eastern and southern parts of the country owing to the small land holdings per farmer in these regions and high cultivation of rice crops. Overall power tiller density is 2.21 per thousand hectare of net sown area. The power tillers

[5]Mechanization for Rural Development: A Review of Patterns and Progress from around the World, Integrated Crop Management, Food and Agriculture Organization of the United Nations, Volume- 20, Rome, 2013, 106.

[6]Gyanender Singh, Agricultural Machinery Industry in India (Manufacturing, Marketing and Mechanization Promotion), Central Institute of Agricultural Engineering, Bhopal, 155.

[7]Mechanization for Rural Development: A Review of Patterns and Progress from around the World, Integrated Crop Management, Food and Agriculture Organization of the United Nations, Volume- 20, Rome, 2013, 108-09.

[8]Gyanender Singh, Agricultural Machinery Industry in India (Manufacturing, Marketing and Mechanization Promotion), Central Institute of Agricultural Engineering, Bhopal, 159-160.

[9] Sukhpal Singh, *Agricultural Machinery Industry in India: Growth, Structure, Marketing and Buyer Behaviour*, Allied Publishers, Publication no. 230, New Delhi, 2010, 30.

[10]VST Tillers Tractors Limited.

market in India is dominated by VST Tillers Tractors Ltd., Banglore (Karnataka) and Kerala Agro Machinery Corporation Ltd. (KAMCO), Athani (Kerala).[11]

Figure 1 Power Tiller

Source: State of Indian Agriculture 2012-13, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 53.

Harrow: There are different types of harrows with tines and spring teeth but the one most commonly used is the disc harrow. Under certain conditions, the disc harrow is the only implement used in preparing fields for planting small grains. Disc harrows are made in single-action and double-action types. Most of the double-action harrows and some of the single-action harrows are designed for use with the tractor only. The disc harrow has a very different effect from that of tined implements on the soil.[12]

Sprayer: In the matter of plant protection equipment, one indigenous firm was licensed to produce power sprayers with a capacity of 924 sprayers per year with imported engines. The state government had helped with foreign exchange for importing about 2600 engines. About 645 of knapsack type sprayers were imported in 1963-64. For aerial spraying, a small unit of 8 aircraft was available in the country. This was originally established to deal with the locust menace in the desert areas.[13] During 1965-66, 1200 shoulder mounted power sprayer were imported by the State Trading Corporation of India and were sold to cultivators at no profit-no loss basis.[14]

There are different types of sprayers, hand, bucket pump and power sprayer, the flame gun thrower, gas pump and seed dresser all used in India. The power sprayers are worked by small oil engines.[15] A bullock drawn manure spreader was developed to uniformly spread manure in fields by farmers owning bullocks. To work this implement, the power to auger and drum is given from ground wheel through chain and sprockets.[16]

A 2-tonne capacity tractor-operated farmyard manure spreader is developed. It consists of manure spreading unit, feeding auger and slanting platform to convey the farmyard manure to the spreading unit.[17] Intra canopy pesticide application equipment for cotton and pigeon pea and a power tiller-operated 2-row canopy sprayer is developed.[18]

The boom sprayer attachment consists of two aluminium hollow sections (50 x 25 millimetre) of 4 metre length with 16 numbers of nozzles. The nozzles are spaced at 450 millimetre apart. A reciprocating pump (40 metre x 25 millimetre) is mounted on the power tiller with the help of a stand. It is light in weight and easy in handling, suitable for spraying in row crops. This result is 55 percent saving in cost, as compared to knapsack power sprayer.[19] Air-assisted spraying system is found more efficient for application of pesticides to control insects and pests as compared to knapsack, aero-blast and boom sprayers.[20]

[11]Trends of Agricultural Mechanization in India, Report of Central Institute of Agricultural Engineering Bhopal and Indian Council of Agricultural Research, Issue no.2, New Delhi, 2014, 5.

[12] D.A. Gadkary, *Mechanical Cultivation in India*, The Manager of Publications, Delhi, 1957, 22-23.

[13] Report on Agricultural Development Problems and Prospective, Government of India, New Delhi, 1964, 42.

[14]Progress Report on Second Five Year Plan, Government of Punjab, Chandigarh, 1956-61, 51.

[15]D.N. Kherdekar, *Agricultural Engineering for Extension Workers*, Ministry of Food and Agriculture, New Delhi, 1959, 55-56.

[16]Annual Report 2011-12, Indian Council of Agricultural Research, Government of India, New Delhi, 66.

[17]Annual Report 2008-9, Indian Council of Agricultural Research, Government of India, New Delhi, 84.

[18]Annual Report 2009-10, Indian Council of Agricultural Research, Government of India, New Delhi, 87.

[19]Small Agricultural Machinery and Implements, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 2012, 59.

[20] Annual Report 2011-12, Indian Council of Agricultural Research, Government of India, New Delhi, 66.

Figure 2 Power Tiller Operated Boom Sprayer

Source: Small Agricultural Machinery and Implements, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 2012, 59.

Figure 3 Aeroblast Sprayer

Source: State of Indian Agriculture 2012-13, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 53.

Figure 4 Battery operated low volume Sprayer (knapsack)

Source: Small Agricultural Machinery and Implements, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 2012, 30.

Figure 5 Engine operated Power Sprayer

Source: Small Agricultural Machinery and Implements, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 2012, 63.

Seed Drill: In recent times broadcast or *Chhatta* methods are used in different areas. There is a tractor drawn seed drill used in India. There are four types of feed in use: (i) cup feed (ii) disc feed (iii) external force feed and (iv) internal force feed. This seed drill is used to sow wheat and maize.

During 1950, the tractor driven seed drills was imported to India and it was found only with the government and some private farms. The prototype of seed-cum-fertilizer drills were designed and developed by Research Development Department and agricultural engineers of various institutions and research centers. The Massey Ferguson seeding attachment mounted on a tine cultivator from U.K. was adopted by farmers. Using the design, some manufacturers made models of tractor operated drills. Swastik limited, Secunderabad (A.P.), manufactured animal and tractor operated drill in early 1960. This design was developed by the joint efforts of Indian agricultural engineers and Ford foundation specialists.[21]

National Agro Industries are the first innovator and manufacturer of zero till fertilizer seed drill in India. They started the manufacturing of national zero till seed drills in 1994 with the co-operation and guidance of G.B. Pant University of Agriculture and Technology, Pant Nagar (Uttaranchal). Till now they have manufactured about 4500 national zero till fertilizer-seed drills. They manufactured more than 800 drills in every sowing season. After seeing the performance of national zero till fertilizer-seed drill, the department of agriculture of Punjab and Haryana, UP and Uttaranchal states has provided the subsidy on this machine.[22] The zero till drill is preferred by farmers from Indo Gangetic plains particularly in northern states of India.

For precise application of seed and fertilizer, mechanically metered seed drills and seed-cum-fertilizer drills operated by tractors have been developed and are being manufactured to suit specific crops and regions.[23]

The zero till seed-cum-fertilizer drill (unit price of Rs 3,500) is used for direct seeding of wheat and placement of fertilizer without preparatory tillage under high soil moisture condition and this is more cost effective.[24] A power tiller-operated zero-till drill is designed for hilly regions. The field performance of zero-till drill was carried out at Palampur University farm in 2009 and at farmer's fields.[25] A 7-row (30 centimetre row spacing) controlled traffic rotary no-till slit drill for sowing of soybean and wheat crop is developed.[26]

Figure 6 Tractor operated Seed cum Fertiliser Drill

Source: State of Indian Agriculture 2011-12, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 66.

[21]S.R.Vena, 'Seed-cum-Fertilizer Drills in India', Small Farm Equipments for Developing Countries: *Proceedings of the International Conference on Small Farm Equipments for Developing Countries*, Past Experience and Future Priorities, 2-6 September, 1985, 256.

[22] National Agro Industry, India.

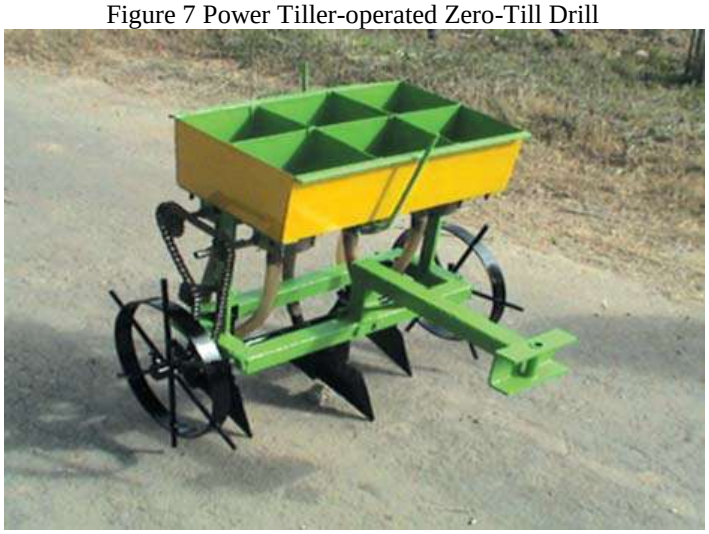
[23]Gyanender Singh, Agricultural Machinery Industry in India (Manufacturing, Marketing and Mechanization Promotion), Central Institute of Agricultural Engineering, Bhopal, 161.

[24] Annual Report 2008-09, Indian Council of Agricultural Research, Government of India, New Delhi, 81.

[25] Annual Report 2011-12, Indian Council of Agricultural Research, Government of India, New Delhi, 67.

[26]Annual Report 2008-9, Indian Council of Agricultural Research, Government of India, New Delhi, 84.

Figure 7 Power Tiller-operated Zero-Till Drill



Source: Annual Report 2011-12, Indian Council of Agricultural Research, Government of India, New Delhi, 67.

Planter : Tractor operated seed planter was developed in the late 1960.[27] The market for rice transplanters in India was not thriving till 5-6 years back as the rice transplantation was done completely manually with the use of labour. Presently, many companies in India are importing rice transplanters from China and Korea and marketing them in all regions of the India. The industry is expected to grow more with Chhattisgarh, Odisha, Bihar and southern states showing positive sign of adoption of technology. The rice transplanter market in India is dominated by players from south India, they are VST Tillers Tractors Ltd., Yanmar India and Kubota Agricultural Machinery India Pvt. Ltd.[28] A customized raised bed maker planter-cum-cultivator for field trials is developed.[29]

Tractor-mounted hill drop planter: A hill drop planter is developed with cup feed seed metering, constructional simplicity and suitability for various crops. It follows the undulations on the field with hill-to-hill spacing adjusted by varying the number of legs on the end wheel. Groundnut and maize are sown with the machine. The row spacing and hill spacing are found to be uniform. Thinning can also be carried out with ease.[30]

Self-propelled paddy transplanter can transplant mat-type seedlings in 2 hectare/day with four persons. Labour requirement with the self-propelled paddy transplanter is 16–20 man-hour/hectare and it is 200–220 man- hour/hectares by the manual method.[31] The manual rice transplanter consists of floats made of marine plywood, seedling tray that accepts the mat type nursery, a tray indexing mechanism and pickers for planting seedlings. When the operator pulls the machine and operates the handle, the picker, six in number, gathers two or three seedlings and place them in the puddled soil.[32]

Automatic potato planters are ideal planting machine for small and big farms and suitable for minimum 45 horse power tractors. Ability to make the bed with disc and mould plough, with its quick and easy adjustments together with many other features make these planters superior in planting performance.[33]

[27]S.R.Vena, 'Seed-cum-Fertilizer Drills in India', Small Farm Equipments for Developing Countries: *Proceedings of the International Conference on Small Farm Equipments for Developing Countries*, Past Experience and Future Priorities, 2-6 September,1985, 256.

[28]Trends of Agricultural Mechanization in India, Report of Central Institute of Agricultural Engineering Bhopal and Indian Council of Agricultural Research, Issue no.2, New Delhi, 2014, 6.

[29]Annual Report 2008-9, Indian Council of Agricultural Research, Government of India, New Delhi, 84.

[30]Annual Report 2009-10, Indian Council of Agricultural Research, Government of India, New Delhi, 87.

[31] Annual Report 2011-12, Indian Council of Agricultural Research, Government of India, New Delhi, 68.

[32]Small Agricultural Machinery and Implements, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 2012, 20.

[33] Ibid, 159.

Figure 8 Animal drawn automatic Sugarcane Planter

Source: Small Agricultural Machinery and Implements, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 2012, 119.

Figure 9 Tractor drawn Sugarcane Cutter Planters

Source: Small Agricultural Machinery and Implements, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 2012, 130.

Figure 10 Rice Transplanter

Source: State of Indian Agriculture 2011-12, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 66.

Figure 11 Animal drawn Potato Planter

Source: Small Agricultural Machinery and Implements, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 2012, 157.

Figure 12 Tractor drawn Potato Planter

Source: Small Agricultural Machinery and Implements, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 2012, 159.

Power tiller-operated bench tracer cum leveler is good for hilly region. The width of the bench terraces in the hills range from 2 to 5 metre depending on the slope of the land. A narrower width is recommended for shallow soils so that digging and earth moving will not be too deep. All these jobs are done by manual labour which increases the cost of operation and drudgery. To mechanize the bench terracing work, a mechanical device known as power tiller-operated bench tracer cum-leveler is developed.[34]

Figure 13 Power tiller mounted Terracer-cum-leveler

Source: Small Agricultural Machinery and Implements, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 2012, 14.

[34]Annual Report 2011-12, Indian Council of Agricultural Research, Government of India, New Delhi, 66.

Figure 14 Laser Land Leveler

Source: State of Indian Agriculture 2011-12, Department of Agriculture and Cooperation, Ministry of Agriculture Government of India, New Delhi, 66.

Combine Harvester: The combine is a harvester, thresher and winnower combined into one and it got manufactured in India in 1970 for the first time. Now tractor-powered and self-propelled combine harvesters are being manufactured in India.[35] There were about 400 harvest combines[36] in 1971-72.

In 1980 when nation needed one type of machine which could harvest and thresh the crop simultaneously to reduce the loses of the farmer. Preet, a manufacturer of combine harvesters, agriculture tractors and agricultural implements started the supply. Initially the company was producing straw reapers, threshers and other agricultural implements. They continued their research and development work and they introduced Preet-987, the most successful self propelled combine harvester of India.[37] In 1989, they developed a successful self-propelled combine harvester and in 1990 tractor driven reaper was launched.[38]

Tractor-powered and self-propelled combine harvesters are being manufactured in India. Track-type combine harvesters, especially suitable for paddy crop, are also being manufactured locally. The combine harvesting of wheat, paddy and soybean has been well accepted by farmers. Apart from the work force availability problems, the usage of combined harvesters has helped in timely harvesting of grains avoiding losses due to adverse weather conditions. The demand of combine harvesters for harvesting wheat crop in Punjab, Haryana and Uttar Pradesh encouraged the local manufacturers to develop local combines. More than 48 manufacturers, mainly in Punjab, produce self-propelled and tractor operated combines for harvesting wheat, paddy, soybean and gram. The entrepreneurs from Rajasthan and Punjab provide combine harvesting services to the farmers of Maharashtra, Gujarat, Madhya Pradesh, Andhra Pradesh and Tamil Nadu.[39]

The tractor mounted combine harvesters occupy around 60% of the total combine harvesters market in India and is mainly concentrated in southern states viz. Tamil Nadu, Kerala, Andhra Pradesh and Karnataka of the country on custom hiring. This is followed by self-propelled combine harvesters which represent 40% of the market. Tractor operated combine harvester, costing about 60-70% of the self propelled combine are owned individually by farmers with large size farms (> 4 hectare). The self-propelled combines are largely owned by custom-hiring contractors.[40]

A tractor operated baler with reaping attachment is developed in collaboration with indigenous baler manufacturer in Punjab.[41] A tractor-drawn straw reaper with trailer is redesigned with the straw collection container mounted over the reaper itself to improve field

[35]Gyanender Singh, Agricultural Machinery Industry in India (Manufacturing, Marketing and Mechanization Promotion), Central Institute of Agricultural Engineering, Bhopal, 164.

[36]C.H.Hanumantha Rao, *Technological Change and Distribution of Gains in Indian Agriculture*, The Macmillan Company of India, Delhi, 1975, 11.

[37]Preet Manufacturer of India.

[38]Sukhpal Singh, Agricultural Machinery Industry in India: Growth, Structure, Marketing and Buyer Behaviour, Allied Publishers, Publication no. 230, New Delhi, 2010, 132.

[39]Gyanender Singh, Agricultural Machinery Industry in India (Manufacturing, Marketing and Mechanization Promotion), Central Institute of Agricultural Engineering, Bhopal, 164.

[40]Trends of Agricultural Mechanization in India, Report of Central Institute of Agricultural Engineering Bhopal and Indian Council of Agricultural Research, Issue no.2, New Delhi, 2014, 5.

[41]Annual Report 2009-10, Indian Council of Agricultural Research, Government of India, New Delhi, 86.

manoeuvrability and to simplify loading and unloading.[42] Harvesting and binding of grain crops is done in single operation. It is useful for wheat, paddy, oats, barley and other grain crops.[43]

Figure 15 Combine Harvester

Source: State of Indian Agriculture 2011-12, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 66.

Figure 16 Modified Straw Reaper with Container

Source: Annual Report 2010-11, Indian Council of Agricultural Research, Government of India, New Delhi, 63.

Thrasher: Bullock treading, the common practice for thrashing wheat was slow and strenuous. Bullock drawn thrashers were developed and introduced in India in the 1940 to reduce treading time and reduce drudgery. For these reasons, wheat grower began to look for faster and less tedious ways to thrash wheat. The earliest successful attempt was a bullock-drawn thresher known as the oil thresher.[44] Thrashing was not complete till the grains were separated by winnowing in natural air stream. To overcome this problem, hand-cranked, pedal-operated and power-operated winnowers and the Hoshangabad winnower, a manual blower-cum-cleaner were developed and introduced in the late 1940.[45] Sonalika Agro Industries Corporation started manufacturing multi-crop thresher in 1971. Tractor driven thrashers were 80% and motor driven were 20%.[46]

The use of mechanical thrashers is widespread in the wheat belt. About 0.3 millions of power thrashers were used in India in 1971, concentrated largely in Punjab, Haryana and western Uttar Pradesh, with a capacity to serve 17 percent of the total wheat area (17.5

[42]Annual Report 2010-11, Indian Council of Agricultural Research, Government of India, New Delhi, 63.

[43]Small Agricultural Machinery and Implements, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 2012, 39.

[44]A. Alam,'Wheat Power Threshers in India', Small Farm Equipments for Developing Countries, *Proceedings of the International Conference on Small Farm Equipments for Developing Countries*, Past Experience and Future Priorities, 2-6 September, 1985, 405-06.

[45]A. Alam,'Wheat Power Threshers in India', Small Farm Equipments for Developing Countries, *Proceedings of the International Conference on Small Farm Equipments for Developing Countries*, Past Experience and Future Priorities, 2-6 September, 1985, 406.

[46]Sukhpal Singh, *Agricultural Machinery Industry in India: Growth, Structure, Marketing and Buyer Behaviour*, Allied Publishers, Publication no. 230, New Delhi, 2010, 127.

million hectares) in India in 1971-72.[47] A whole crop maize thrasher is developed for shelling and conversion of stalk to chaff in a single operation. Field testing with whole crop of maize give the output of 210 kilogram/hour. A tractor-operated multi-crop thrasher is also modified with similar arrangement and tested on the farmer's field.[48] An automatic chain type feed conveyor is developed for commercial multi-crop threshers for enhanced comfort and safety of the users. This improved feeding system saving cost and time, respectively as compared to the manual feeding by the conventional method.[49]

The thrashers (multi-crop and paddy), planters and zero till drill in India is highly un-organized and is dominated by large number of small and medium scale enterprises (SMEs) located majorly in the states of Punjab, Haryana, Uttar Pradesh, Bihar, Madhya Pradesh, Gujarat, Maharashtra, Tamil Nadu and Andhra Pradesh. The trend is towards use of tractor operated high capacity thrashers on custom hiring mode.[50]

Figure 17 Multi-crop Thrasher

Source: Small Agricultural Machinery and Implements, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 2012, 41.

Chaff Cutter: There are hand fodder cutters and others driven by mechanical power (oil engine or electricity) which cut from 30 to 60 maunds of fodder per hour. These machines require 2 to 5 horsepower engines or electric motors. A large number of chaff cutters are manufactured locally every year.[51] High capacity mobile chaff cutter-cum-blower loader is found suitable for chaffing fodder crops and residues ranging from soft stemmed crops such as Berseem, Guinea, Napier, Cenchrus to stiffer stemmed crops such as Maize, Sorghum and Oats. It is operated with tractor.[52]

Figure 18 Fodder Chopper cum Loader

Source: Amar Fodder Chopper cum Loader

[47]C.H.Hanumantha Rao, *Technological Change and Distribution of Gains in Indian Agriculture*, The Macmillan Company of India, Delhi, 1975, 11.

[48]Annual Report 2009-10, Indian Council of Agricultural Research, Government of India, New Delhi, 87.

[49] Annual Report 2010-11, Indian Council of Agricultural Research, Government of India, New Delhi, 64.

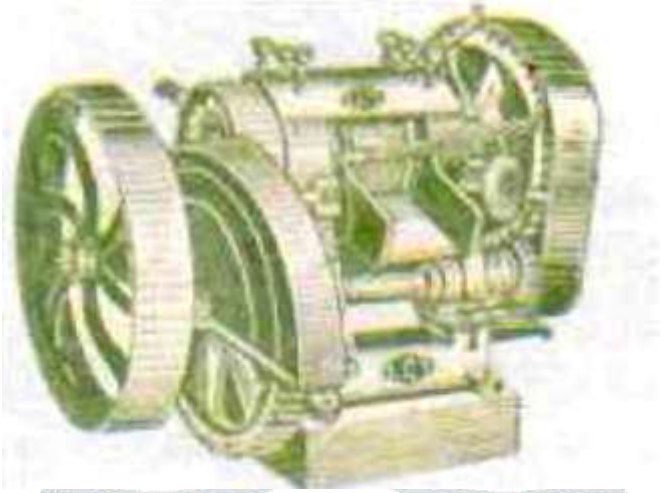
[50]Trends of Agricultural Mechanization in India, Report of Central Institute of Agricultural Engineering Bhopal and Indian Council of Agricultural Research, Issue no.2, New Delhi, 2014, 5.

[51] Punjab Agriculture Facts and Figures, Economic and Statistical Organization, Government of Punjab, Publication No.II, 1957, 175.

[52] Annual Report 2010-11, Indian Council of Agricultural Research, Government of India, New Delhi, 63.

Sugarcane Crusher: The vertical type sugarcane crusher consists of crushing roller and extracting roller. The crusher can be operated either by a pair of bullocks or electric motor stationary engine with gear drive. The rollers are made of special grade cast iron. The machine is operated by electric motor or stationary engine.[53]

Figure 19 Sugarcane Crusher (Horizontal type)



Source: Small Agricultural Machinery and Implements, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 2012, 124.

Tube Well and Pumping sets: Electricity is an essential input in modernized agriculture. Many studies made in the 70's showed that electricity makes a significant contribution to the development of agriculture. Most importantly electric pumps are cheaper in capital and operational costs than diesel pumps. At independence hardly 1300 villages had been electrified and only 6400 energized pump-sets were working in the entire country. A tube-well gives requisite quantity of irrigation water on a 'push-button' basis.[54]

Pumping from wells using mechanical power, either oil or steam engines was becoming more and more common in this country.[55] The construction of tube-wells started in India since 1930 and by 1950 nearly 2500 tube-wells were constructed in U.P and Bihar. In 1951-52, there were about 2,500 tube-wells in India, of which 2,300 were in U.P.[56] At the end of 1960-61, the number of tube-wells actually working in the states was 9,188, which rose to 11,194 at the end of 1965-66. Similarly the area irrigated by tube-wells rose from 9.95 lakh hectares in 1960-61 to 14.25 lakh hectares in 1965-66.[57]

The use of modern more efficient means of irrigation, especially installation of pump-sets, tube-wells gained popularity. This is indicated that the number of diesel and electric pumping sets in the country increased from 9.79 lakhs in 1965-66 to 14.24 lakhs in 1967-68. The number of state tube wells increased from 12 thousand to 14 thousand between 1965-66 and 1967-68.[58] In 1969-70, an additional 2,60,00 electrical pump-sets were energized and 90,000 additional tube-wells were installed.[59] About one-half of the total area under tube-well irrigation in the country (51.7 percent) lied in U.P. Punjab was another 26 percent and Haryana 10.6 percent the three states together accounting for 88.3 percent, of the total tube well fed irrigated area of the country (1976-77).[60]

The number of pump sets energized rose from 0.2 million in 1950-51 to 11.2 million by 1989-90.[61] The net sown area has remained around 141 million hectares during the last 40 years. The cropping intensity, i.e., the ratio of gross cropped area to net cropped area, has however, gone up from 118 percent in 1970-71 to 138 percent in 2008-09.[62]

[53]Small Agricultural Machinery and Implements, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi, 2012, 124.

[54]R.N.Chopra, *Green Revolution in India the relevance of Administrative Support for Its Success: A Case Study of Punjab, Haryana, U.P. and Bihar*, Intellectual Publishing House, New Delhi, 1985, 93.

[55]C.P.Dutt and B.M.Pugh, *Farm Science*, Kitabistan, Allahabad, 1940, 115.

[56]K.P.Bhatnagar, *Indian Rural Economy*, Kishore Publishing House, Kanpur, 1960, 173-175.

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[61]Eight Five Year Plan, Planning Commission, Government of India, New Delhi, 61.

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Table 2 Number of Tube-wells in India (numbers)

Year	Tube-wells	
	Oil engine pumps	Electric pumps
1945	12,062	8562
1951	82,477	26,174
1956	122,511	47,934160,1
1961	229,972	68
1970	1.546	1.629
1980	3.101	4.330
1990	4.659	6.01
2000	6.465	9.525
2009-10	8.456	16.194

Source: Central Statistical Organisation, Ministry of Agriculture and Co-operation, Government of India, New Delhi, 1965,69-70.

Table 3 Net Area Irrigated in India by Tube-wells in 2009-10(Thousand Hectare)

State/U.T.	Tube-wells
Andhra Pradesh	1696
Arunachal Pradesh	-
Assam	7
Bihar	2339
Chhattisgarh	297
Goa	5
Gujarat	1124
Haryana	1783
Himachal Pradesh	16
Jammu & Kashmir	3
Jharkhand	25
Karnataka	1252
Kerala	18
Madhya Pradesh	2087
Maharashtra	2171
Manipur	-
Meghalaya	-
Mizoram	-
Nagaland	-
Orissa	329
Punjab	2956
Rajasthan	2580
Sikkim	-
Tamilnadu	391
Tripura	6
Uttrakhand	214
Uttar Pradesh	9619
West Bengal	-
Andaman & Nicobar island	-
Chandigarh	1
Dadra & Nagar Haveli	0
Delhi	20
Daman & Diu	-
Lakshadweep	-
Pondicherry	10
India	28948

Note: (-) = Nil

Source: Statistical Abstract of Punjab 2012, Economic and Statistical Organization, Government of Punjab, Publication no.938, Chandigarh, 166.

Conclusion: Farm mechanization has played a critical role in improving agricultural production as well as productivity through timeliness of field operations and by enabling proper and efficient use of inputs. A number of successful farm machineries have been developed and commercialized during the past six decades. It implies the use of various improved farm tools and equipment to reduce the drudgery involved in the work and to enhance the overall productivity and production with the lowest cost of production.

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