Advanced Agricultural Research & Technology Journal ▪ Vol. III ▪ Issue 1 ▪ JANUARY 2019 ISSN: 2581-3749 (online)

IMC-2018 Special

Mechanization in Horticulture Crops: Present Status and Future Scope

Y. P. Khandetod*

College of Agricultural Enginnering and Technology (DBSKKV), Dapoli, Dist Ratnagiri, Maharashtra (India) 415712

Abstract

Mechanization plays a vital role in securing the future of fruit growers in developed countries. The demand for sustainable mechanization and services will continue to rise naturally with a growing population's demand for food, feed and biological industrial raw materials from agriculture and horticulture. Mechanization is necessary because of the rural migration, as the younger generation responds to economic opportunities in the agricultural service sectors as well as non-agriculture sectors, and with the growing urban employment and improved quality of life. In situations where family labour remains the main source of farm power, there is also a need to reduce labour requirement and improve labour productivity as well as total output so that child labour and drudgery can be eliminated. The machinery improves the farmer's ability to perform operations in a timely manner. It also reduces the risks associated with the need for large amounts of seasonal labour for short periods of time and lessens the social problems. It is important to encourage sustainable private sector development that can offer farmers the right choice of technology at the right price to increase productivity to support rural economic development, contribute to local and national food security, reduce post-harvest losses and promote local manufacturing of equipment and machinery.

The modern day horticultural mechanization includes various growing techniques and production processes, working operations, technical procedures, appropriate techniques for soil management systems, orchard tractors, machines for working the soil, machines for mulching and mowing grass, post hole diggers, spreaders, sprayers, front-fitted knife trimmers, harvesting machines, transporting equipment, shakers, harvesters etc. The harvesting, pruning and spraying are still a manual task and need to be mechanized. The average farm power density in India is 1 kW ha^{-1}. Power availability during crucial period of operations causes limitation in timeliness. Required power density to achieve timeliness of operations is estimated as 3.75 kW ha$^{-1.}$

The demand for sustainable mechanization and services will continue to rise with a growing demand for food, feed and biological industrial raw materials from the rural infrastructure, domestic supply chains and service providers. Local manufacturers and world markets in equipment and machinery are all of vital importance. It is crucial that multidisciplinary research, involving plant scientists, engineers, food scientists, economists and marketing expertise needs to be focused on creating new production systems. Innovation will come through intimate understanding of the system. Growing systems need to be designed for specific crops and then dedicated machines will fit. Mechanization and robotics for fruit harvesting, grading and packing remains more of a problem than for vegetables. The study of various control systems such as pneumatic, hydraulic, hydro-pneumatic and electrical control reveals that the use of hydraulic control system will be more beneficial and reliable for horticultural crop harvesting equipment.

Key words: Mechanization, shakers, marginal farmer, Persian wheel.

Introduction

Increasing demand for industrialization, urbanization, housing and infrastructure is forcing conversion of agricultural land to non-agricultural uses. The scope for expansion of the area available for cultivation is limited. Small and marginal holdings of less than 2 hectare account for 85 % of the total operational holdings and 44 % of the total operated area. The average size of holding for all operational classes (small and marginal, medium and large) have declined over the years. The availability of labour to work in agriculture is crucial

Corresponding author: ypkhandetod@rediffmail.com
Received Date: 10.5.2018 : Accepted Date: 24.12.2018

in sustaining agricultural production. The population dynamics of Indian agricultural workers shows that by 2020, the population of agricultural workers in the country will be about 230 million of which 45 % will be the female workers. It is predicted that the population in rural areas will decrease to 62.83 % in 2025 and to 44.83 % in 2050. Thus, there is going to be a significant role of farm workers in country's agricultural production. India is the second most populous country in the world with an estimated population of 1.25 billion in 2014 and an annual growth rate of 1.3 per cent. About two-third of the population live in rural areas with about 50 per cent still dependent on agriculture for their livelihood. Mechanization plays a vital role in securing the future of fruit growers in developed countries .The demand for sustainable mechanization and services will continue to rise naturally with a growing population's demand for food, feed and biological industrial raw materials from agriculture and horticulture.

Horticulture accounts for 30 % of India's agricultural GDP (Gross Domestic Product) from 8.5 % of the cropped area and it is a priority sector in agriculture by virtue of its potential in improving the socio-economic conditions of the farmers. In era of commercial and high value agriculture, horticulture crops are front runners for betterment of small and marginal farmer in the India. Mechanization is necessary because of the rural migration, as the younger generation responds to economic opportunities in the agricultural service sectors as well as non-agriculture sectors, and with the growing urban employment and improved quality of life. In situations where family labour remains the main source of farm power, there is also a need to reduce labour requirement and improve labour productivity as well as total output so that child labour and drudgery can be eliminated. The machinery improves the farmer's ability to perform operations in a timely manner. It also reduces the risks associated with the need for large amounts of seasonal labour for short periods of time and lessens the social problems.

Brief History of Mechanization

Blacksmiths and carpenters have been the traditional fabricators of agricultural equipment in India. The early agricultural mechanization in India was greatly influenced by the technological development in England. In 1889, Watts and Kaisar introduced ploughs,

Table 1. Sequence of Mechanization.

	First stage	Second stage	Third stage
Type of operation	High power Low skill/control	Medium power Medium skill	Varying power High skill/control
Stationary	Grinding, milling, crushing, pumping, threshing	Grinding by size, cleaning	Grinding by quality
Mobile	Land preparation, transport	Seeding of grain, harvesting of grain	Transplanting, harvesting of fruits and vegetables, sugarcane, cotton

Table 2. Aspects of Indian Agriculture (1960-2010).

Item	1960	1970	1980	1990	2000	2010
Agricultural land (million ha)	133	140	140	143	143	142
Irrigation pumps (million)	0.4	3.3	6.2	12.9	19.5	28.0
Irrigated area (per cent)	19	22	28	33	34	35
Cropping intensity	1.15	1.18	1.23	1.30	1.33	1.36
Fertiliser use (kg ha^{-1})	2	15	39	88	125	160
Grain yield (kg ha^{-1})	700	860	1000	1300	1600	1950
Tractors (thousands)	37	146	531	1200	2600	4000
Area per tractor (ha)	3600	960	260	120	55	36
Power tillers (thousand)	0	9.5	16	31	100	200
Draught animals (million)	80.4	82.6	73.4	70.9	60.3	50.0

corn grinders and chaff cutters Cawnpore (now Kanpur) Experimental Farm in Uttar Pradesh. Sardar Joginder Singh (1897-1946), who was the agriculture Minister in the Punjab Government (1926-37), introduced the steam tractors in India in 1914 for reclamation of waste land and eradication of 'Kans'. Horse drawn

Table 3. Land Holdings in India

	Percentage number of holdings in each category				Area under each category			
					Percentage			Average (ha)
Category	1971	1991	2001	2011	1991	2001	2011	2011
Marginal (<1 ha)	50.6	59.2	62.4	67.0	15.0	18.7	22.2	0.38
Small (1-2 ha)	19.0	18.7	19.1	17.9	17.4	20.2	22.1	1.42
Semi-Medium (2-4 ha)	15.2	13.6	11.9	10.1	23.2	23.9	23.6	2.71
Medium (4-10 ha)	11.3	7.0	5.6	4.3	27.1	24.0	21.2	5.76
Large (>10 ha)	3.9	1.5	1.0	0.7	17.3	13.2	10.9	17.37
Average holding size (ha)	2.28	1.57	1.33	1.16				
All holdings (million)	70.5	106.6	119.9	137.8				

Source: (MOA, 2013).

Table 4. Trend in Mechanization Inputs Adoption as per Size of Farm Holdings

Years	Farm holdings (ha)					
	Marginal (< 1)	Small (1-2)	Semi-medium (2-4)	Medium (4-10)	Large (10 & above)	All Sizes
			Bullock drawn steel ploughs (million)			
1982	5.163	2.798	2527	2.186	0.669	13.344
1987	7.180	4.685	3.991	3.137	0.841	19.842
1992	12.527	5.565	4.605	4.107	1.295	28.098
Growth %	9.27	7.10	6.18	6.50	6.83	7.73
			Bullock drawn disc harrows & cultivators (million)			
1982	4.569	5.198	5.083	4.669	1.402	20.921
1987	4.667	5.968	5.368	5.251	1.380	20.64
1992	5.473	5.881	5.369	3.897	0.997	21.617
Growth %	1.82	1.24	0.55	-1.79	-3.35	0.33
			Tractors (million)			
1982	0.033	0.042	0.105	0.199	0.108	0.489
1987	0.264	0.231	0.387	0.486	0.209	1.580
1991	0.387	0.764	0.633	0.625	0.356	2.765
Growth %	27.91	33.65	19.68	12.12	12.67	18.91
			Pump sets (million)			
1982	1.273	1.580	1.975	1.875	0.627	7.330
1987	3.033	2.755	3.029	2.665	0.819	12.317
1991	4.911	4.181	3.469	2.788	0.866	16.216
Growth %	14.45	10.22	5.79	4.04	3.28	8.26
			Threshers (million)			
1982	0.139	0.113	0.203	0.235	0.078	0.768
1987	0.353	0.357	0.472	0.513	0.224	1.917
1991	18.83	13.50	7.64	6.64	5.64	11.03
Growth %	18.83	13.50	7.64	6.64	5.64	11.03

Note: Difference in population of agricultural machinery is due to secondary data quoted from two separate sources i.e. Input Survey and Livestock Census data. Source: Input Survey 1981-82, 1986-87and 1991-92, Ministry of Agriculture, Government of India.

and steam tractor operated implements were imported during the latter part of the 19th century. The horse drawn equipment imported from England were not suitable for bullocks and he-buffaloes used in India and thus, were modified by small scale manufacturers to suit Indian draught animals. With the establishment of Allahabad Agricultural Institute, Allahabad in 1942, the development activities in agricultural machinery accelerated and as a result bullock drawn Meston, Shabash and Wah-Wah ploughs were introduced in Uttar Pradesh, manufactured by the Agricultural Development Society, Naini in early forties. The Indian farmers gradually responded to farm mechanization technology especially after Green revolution in 1960s. High yielding varieties with assured irrigation and higher rate of application of fertilizer gave higher yields and better economic returns. This enabled the farmers to start adopting mechanization. The development of power thresher with integrated Bhusa making attachment and aspirator blower and mechanical sieves for grain and straw separation in 1960s was the major achievement of Indian engineers which was widely adopted by our farmers. Gradually demand for other farm machinery such as reaper and combine harvester also increased. Demand of tractors in the country was met through importation until 1961 when Eicher Tractors Ltd. and Tractors and Farm Equipment Ltd started manufacturing tractors with foreign collaborations. To meet the additional demand, importation continued up to 1977. Meanwhile many other industries started manufacturing tractors with foreign know how 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 industries started manufacturing tractors since then with indigenous and foreign know how.

Development of Agricultural Mechanization

The first tractor to India was brought in 1914. In 1930s pump-sets were introduced in the country. In the 1940's, high horsepower crawler tractors were imported under the aegis of Central Tractor Organization (CTO) mainly for land development and to eradicate obnoxious weed *kans* grass. At the time of Independence, Indian farmers used mostly bullock-drawn ploughs and wooden planks for pulverization, compaction and smoothening. Hand tools like spades, pick axe, crowbars, hoe, sickle and chopper were in use. For irrigation, watering buckets and Persian wheels and for transportation bullock carts were in use. In late 1950s, manufacturing of irrigation pump-sets started. There were only about 8,000 tractors in 1950 and these increased to 39,000 units in 1960. Engines (petrol, kerosene and diesel) were being used for post-harvest processing like floor making, rice milling, grinding, etc. During the period 1960-1980, more than 90 per cent of public investment in agriculture was for the development of irrigation facilities including medium and major irrigation projects. The result was a significant increase in the area under irrigation, particularly in the states of Punjab, Haryana and Uttar Pradesh. Application of engineering in agriculture was equally appreciated by the farmers and to-day they feel proud to have improved machinery from bullock drawn harrows to rotavators,

Table 5. Tractor sales during 2007-08 to 2013-14.

Manufacturer	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Force Motors	2092	1067	614	1016	1743	1886	3219
Escorts	47213	43286	54037	66148	62636	61282	68060
HMT	4687	4109	4901	4920	3639	3320	1483
M&M Group	129260	133514	176790	215975	238269	213508	259907
Tafe Group	78847	76609	97935	114515	146112	131617	157052
VST	1714	2329	3761	4729	7033	5895	7266
JD	28528	31402	37131	53544	55849	29819	37478
NHI	23240	21002	22950	32076	34990	27137	32222
Same Deutz-Fahr		4172	3631	5612	6785	1318	1923
Sonalika	30920	29520	38561	46574	50603	50849	65541
Total	346501	347010	440331	545109	607658	641845	634151

Source: TMA (2007 to 2014)

Table 6. Population of Power Sources and their power availability in India.

Year	Agriculture Workers		Draught Animals		Tractors		Power Tillers		Diesel Engines		Electric Motors	
	Million	Power (kW ha^{-1})	Million	Power (kW ha^{-1})	Million	Power (kW ha^{-1})	Million	Power (kW ha^{-1})	Million	Power (kW ha^{-1})	Million	Power (kW ha^{-1})
1971-72	125.67	0.045	78.42	0.133	0.119	0.02	0.016	0.759	1.443	0.053	1.535	0.041
1975-76	133.75	0.048	77.52	0.135	0.207	0.04	0.023	1.110	2.075	0.078	2.064	0.056
1981-82	146.77	0.051	76.21	0.128	0.513	0.09	0.032	1.562	3.061	0.112	3.203	0.084
1985-86	161.09	0.057	75.36	0.129	0.746	0.14	0.040	1.971	3.742	0.139	4.192	0.111
1991-92	185.24	0.065	74.11	0.126	1.244	0.23	0.060	3.020	4.800	0.177	6.019	0.159
1995-96	200.98	0.071	73.30	0.124	1.734	0.32	0.082	4.098	5.528	0.203	7.464	0.196
2000-01	222.55	0.079	72.31	0.122	2.599	0.48	0.122	6.112	6.466	0.238	9.525	0.250
2005-06	246.44	0.087	71.34	0.120	3.819	0.70	0.181	9.035	7.432	0.273	11.866	0.311

Source: 1. Power Availability in Indian Agriculture, 2000, CIAE, Bhopal, India
2. Agricultural Research Data Book 2003, IASRI, New Delhi

Persian wheel to drip and micro-sprinkler systems, cone-dibblers to pneumatic planters, sickles to combine harvesters, sieve to colour sorters, and, kolhus to solvent extraction plants, and hand mills to roller flour mills, etc. The farmers are not afraid of hot/cold desert and vagaries of weather as they have green houses and low tunnel plastic houses technology to grow crops in any place at any time of the year. During the era of Green evolution, provision of a range of inputs such as agro-chemicals and farm machinery contributed increasing agricultural productivity. The availability of farm power registered a significant increase due to enhanced contributions from electrical and mechanical sources. During 2012-13 the average farm power available country-wide was about 1.84 kW ha^{-1} which comprised about 90 per cent from mechanical and electrical sources and only about 10 per cent from animal power and human labour (Mehta 2013). It is important to encourage sustainable private sector development that can offer farmers the right choice of technology at the right price to increase productivity to support rural economic development, contribute to local and national food security, reduce post-harvest losses and promote local manufacturing of equipment and machinery.

Size of Land Holdings and Mechanization

The size of land holding is very important factor in adaption of mechanization. The average size of land holdings in 2011 was 1.16 ha with only 0.7 per cent (1.0 million) consisting of farms of more than 10 ha but constituting about 11 per cent of the cultivated land while the farms of less than 1 ha (over 67 per cent) constitute about 22 per cent of the cultivated land the rest of the farms are in the intermediate range with the largest proportion being medium farms (4 to 10 ha) and semi-medium farms (2 to 4 ha) which cultivated 24 per cent each of the total cultivated land in 2011.

Thus the three categories comprising large, medium and semi-medium farms (20.7 million farm holdings) cultivate between them 56 per cent of the cultivated land – it is apparent that these three categories of farmers have been instrumental not only for the success of agricultural mechanization in India but for the overall success of the Green Revolution and the remarkable transformation of the food security situation over the past 50 years.

Adoption of improved machinery.

Mechanization technologies were first adopted by the large farmers (over 10 ha farm size) followed by medium scale farmers (with 4 to 10 ha farm size). The Indian farmers gradually responded to farm mechanization technology especially after Green revolution in 1960s. The use of farm machinery depends upon the farm power sources available in the country for various tractive and stationary operations. Human and animal power, the two 'renewable energy' or 'bio-energy' sources, have traditionally been used for various farm operations. The crops are protected from pests, diseases and from weeds, through the application of chemicals. The application of these inputs is achieved through 'human power' in traditional agriculture. Agro-processing includes farm-level processing to improve quality of produce and technology for loss prevention in storage, handling and transport. Major equipment which have been

developed and adapted for farm level processing include cleaners, graders, dryers, shellers, decorticators, storage structures milling equipment etc. Cottage and industrial level secondary processing includes, rice mills, grain mills, dal mills, oil mills, preservation and processing of animals, fruits and vegetables etc. to increase shelf life and their quality. Today more than 73 % of paddy, 55 % maize, 24 % pulses and 45 % oilseeds and 45 % sugarcanes are processed by modern machinery besides other commercial crops.

Power Availability

The state of agricultural mechanization in the country is characterized by large variations in power availability. There is a strong linear relationship between the farm power available and the agricultural output per ha. During 2012-13 the average farm power available country-wide was about 1.84 kW ha^{-1} which comprised about 90 per cent from mechanical and electrical sources and only about 10 per cent from animal power and human labour (Mehta 2013). This underscores the emphasis on the growth and development of power machinery systems in Indian agriculture.

The mechanization saves time and labour, cuts down crop production costs in the long run, reduces post-harvest losses and boosts crop output and farm income. Steady growth was observed in manually operated tools, animal operated implements, and equipment operated by mechanical and electrical power sources in India. In manually operated equipment, the number of sprayers has almost doubled. After liberalization and with development of prototypes of machines, manufacturing got a big boost particularly in Haryana, Punjab, Rajasthan, Madhya Pradesh and Uttar Pradesh states of India.

Horticultural tools and equipments

The horticultural tools include axe, carpentry axe, dah, felling dao, tea prunning dao, billhook, budding knife, grafting knife, budding and grafting knife, prunning and slashing knives, chopping knife, multipurpose chopping knife, cutting knife, prunning secateurs, pneumatic secateurs, chain saw, hedge shear, hedge trimmer, string trimmer, lopping shear, forester shear, grass shear, garden sword, flower scissors, rotating disc mower, cylindrical lawn mower, crow bar, power tiller operated auger digger, post hole digger, potting material mixer etc.

The modern day horticultural mechanization includes various growing techniques and production processes, working operations, technical procedures, appropriate techniques for soil management systems, orchard tractors, machines for working the soil, machines for mulching and mowing grass, post hole diggers, spreaders, sprayers, front-fitted knife trimmers, harvesting machines, picking machines transporting equipment, shakers, harvesters etc. The harvesting, pruning and spraying are still a manual task and need to be mechanized. The average farm power density in India is 1 kW ha^{-1}. Power availability during crucial period of operations causes limitation in timeliness. Required power density achieve timeliness of operations is estimated as 3.75 kW ha^{-1}.

Seed bed preparation

Deshi ploughs bakhar and patela were the most popular traditional implements for seed bed preparation prior to 1960's. Cultivator, disc harrow, mould board plough, puddler, disc harrow-cum-puddler, peg tooth harrow, spring tine harrow, rotavator and patela harrow operated by animal and tractor are the improved implements which have been adopted by farmers The growth in use of tractor drawn machinery has been in the range of 9-17 %. Different sizes of cultivators and disc harrows are used but due to farm road and terrain constraints, cultivators of more than 15 tines and disc harrows of more than 18 discs are not much in use. The power from higher horse power tractors, therefore, is not fully utilized.

Sowing and planting equipment

The line sowing not only saves seed but also facilitates regulated application of fertilizer near root zone. Besides, it helps control of weeds through use of mechanical weeders. The animal drawn Dufan (two row), Tifan (three row), Enatigoru and FESPO plough (all local sowing devices) are used by the farmers as these cover more area and cost less. For precise application of seed and fertilizer, mechanically metered seed drills and seed-cum- fertilizer drills operated by animals and tractors have been developed and are being manufactured to suit specific crops and regions

Interculture and plant protection equipment

Weed control in irrigated and rain-fed agriculture during Kharif is a serious problem and the yield is affected to the extent of 20-60 %, if not controlled. Khurpi is the most popular tool used for removal of weeds but it takes 300-700 man-hours to cover one hectare. Use of long handle wheel hoe and peg type weeders, reduce weeding time to 25-110 hours. Bullock operated weeder and

Table 7. Various Field Operations and Implements.

Crop	Operation	Tools/ implements	Improved implements presently being suggested for introduction
Paddy	Puddling	Wetland puddler	Power tiller operated rotavator
	Transplanting	Manual transplanter	Power operated transplanters, direct seeder
	Weeding and interculture	Manual	Cono weeders
	Harvesting	Manual	Vertical conveyor reaper, combines
	Threshing	Manual, hold on threshers	Threshers, combines
Cereals, pulses and oil seed	Plowing	Bullock Drawn	Tractor /Power tiller
	Sowing	Bullock Drawn/Manual	Tractor /Power tiller
	Weeding and interculture	Bullock Drawn/Manual	Tractor /Power tiller
	Harvesting	Bullock Drawn/Manual	Combines
	Threshing	Bullock Drawn/Manual	Threshers, combines
Coconut	Plant protection	Foot operated sprayers	Tall tree power sprayers
	Weeding and interculture	Long spades, manual	Power tiller operated implements
	Harvesting	Manual	Tree climber, hydraulic operated harvesting ladder
	Dehusking	Manual, foot operated dehusking tool	Improved dehusking Machine
	Drying	Sun drying	Dryers for copra making
Arecanut	Weeding and interculture	Manual	Improved tools and weeders
	Earthing up	Manual	Power tiller mounted implement
	Plant protection	Foot operated sprayer	Tall tree sprayer
	Harvesting	Manual	–
	Drying	Open sun,	Dryers
	dehusking	manual with knife, arecanut nut dehusker	power operated dehusker
Tapioca	Ploughing	Bullock drawn plough	Tractor
	Planting	Manual	Planter
	Interculture	Manual	Power weeders
	Harvesting	Manual digging	Tractor operated harvesters
	Peeling	Manual	Tapioca peeling machine
Sugarcane	Ploughing,	Bullock,	Tractor drawn
	secondary tillage	Manual	Power tiller and tractor rotavators
	Planting	Manual	Tractor drawn planter
	Weeding and interculture	Manual	Small power weeders
	Harvesting	Manual	Improved harvesters

Cashew	Interculture	Manual	Power tiller mounted implements
	Spraying	Foot operated sprayers	Power sprayers and dusters, tree crop sprayers
	Harvesting	Manual	Fruit picker(manual)
	Post-harvest management	Traditional	Improved
Pepper	Planting	Manual	Auger digger
	Interculture	Manual	Improved tools and rakes
	Plant protection	Foot operated sprayers	Tree crop sprayers
	Harvesting	Manual or ladder	Plucking tools
	Post-harvest management	Drying under sun	Dryers for retaining quality
		manual grading	pepper graders
Cardamom	Interculture	Manual	Small power weeders
	Post-harvest management	Drying – curing houses	Electrical-cum- solar powered dryers, high efficiency curing kilns
Tea and Coffee	Interculture	Manual	Small power weeders
	Spraying	Manual	Power sprayers High efficiency sprayers
	Plucking (Tea)	Manual	Tea plucking machine
Vegetables	Field preparation	Manual	Power tillers
	Planting	Manual	Vegetable planter
	Harvesting	Manual	Mechanical harvester
Garden crops	All operations	Manual	Improved horticultural tools
Cardamom	Interculture	Manual	Small power weeders
	Post-harvest management	Drying–curing houses	Electrical-cum- solar powered dryers, high efficiency curing kilns
Coffee	Interculture	Manual	Small power weeders
	Spraying	Manual	Power sprayers High efficiency sprayers
	Plucking	Manual	Tea plucking machine
Mango	Nursery	Manual	Power tiller
	Plant Protection and fertilizer applications	Manual	Power tiller
	Interculture operations	Manual	Small garden tractor and power tiller
	Harvesting	Hand tools	Mechanical harvester
Horticultural Fruit Crops and Flowers	Nursery	Manual	Power tiller
	Plant Protection and fertilizer applications	Manual	Power tiller
	Interculture operations	Manual	Small garden tractor and power tiller
	Harvesting	Hand tools	Mechanical harvester

cultivator are also used for control of weeds. Different designs of low cost hand operated sprayers and dusters are available for plant protection. Spraying in cotton, paddy, sugarcanes, fruits and vegetables, oilseeds and pulses has become popular

Harvesting and threshing

The technology for development of harvesting and threshing equipment is motivated by following factors:

1. Economic considerations-reduction in cost of production and reduction in harvest and post-harvest losses and quality of produce,

2. Social realities- non-availability of labour during the harvesting period and to ensure timeliness, and

3. Ergonomic considerations -reducing drudgery in the operations.

On-farm Post Harvest Technology

Post-harvest technology equipment for On-Farm/ Village level processing may be given greater thrust during the next 10 years for drying of copra, arecanut, pepper, etc. Special dryers for cardamom to obtain best quality produce with retention of green colour and aroma may be introduced in a big way for the benefit of small growers. There are no proper facilities available in this zone for collection, storage and marketing of perishable produce. There is an urgent need to develop suitable mechanism to collect perishable produce from the farmers, store them in cool chambers/cold storage to hold the produce for a short period when there is a glut in the market. There are cold storage facilities for fisheries products. The cold storage facilities for perishable crop produce are to be established in common places among the cluster of villages. Value addition industries like coconut water bottling plant, snowball coconut, coconut chips etc. and by product utilization industries for coconut, cashew and other horticultural crops may be established by encouraging entrepreneurs/Self Help Groups. The by-product industries for coconut, cashew nut shell liquid etc. in Kerala and Karnataka may be improved with modernization. Processing industries for mango and cashew may be set up in Konkan region of Maharashtra. Non-destructive qualitative analytical equipment for assessing quality of export grade mango may be developed for Konkan region. Mechanized cashew nut shellers may be developed for avoiding the manual handling of the CNSL oozing from cashew shells.

Rural Agro-Processing

Decentralized value addition of farm produce helps in better waste management, less transportation, and more employment in rural areas. Primary processing facilities need to be created in rural areas for on farm processing of farm produce to:

- Use available raw materials for processing in the catchment area at reduced cost.
- Reduce cost of processing due to availability of labour, reduced cost of handling, and transport.
- Generate more employment for rural people to arrest the migration and reduce social problems in cities (mitigation of congestion in cities).
- Achieve overall development of rural areas with the creation of other infrastructure to serve these units in terms of education, health, communication, etc.
- Utilize by-products after value addition as animal feed, compost, biogas feed, etc. to reduce pollution load of cities.
- Make better Use of crop residues, processing of by-products and wastes in eco-friendly and economically rewarding fashion.
- Appropriately pack and market the minimally processed and value added products through food chain.

Village craftsmen

Village artisans are the main source of supply and repair and maintenance of hand tools and traditional implements are made by village craftsmen. These include implements and tools like khurpi, spade, sickle, local ploughs, bakhar, sowing devices, yokes, patela, leveller, oil ghanis, grinding wheels, hand mills, hand-operated milk churning tools, winnowing devices, sieves, wooden storage structures, bullock carts, manual water lifting devices etc. If village artisans are properly trained they will accelerate the adoption of mechanization inputs due to their proximity with farmers.

Tiny and small-scale industries

The tiny and small scale units fabricate bulk of improved agricultural machinery such as ploughs, cultivators, disc ploughs and harrows, seed drills, planters, plant protection equipment, reaper harvesters, combine harvesters, threshers, cleaners, graders, mills, crushers, oil expellers, diesel engines, irrigation pumps, dairy machinery etc.

Farm Machinery Training and Testing Institute

Table 8. Projections for Mechanization in India

Sr. No.	Item	2005	2015	2030	2050
1	Draught animals (millions)	53	37	15	5
2	Tractors (millions)	3.0	4.5	6.0	7.0
3	Power tillers (thousands)	152	350	750	900
4	Diesel engines (millions)	6.4	7.3	7.8	8.5
5	Electric motors (millions)	17	25	35	45
6	Power (kW ha^{-1})	1.5	2.0	3.0	4.5

Table 9. List of Standards on Agricultural Machinery

Sr. No.	Type of machinery	Standards Nos.
1.	Tractors and power tillers and engines	160
2.	Soil working equipment	47
3.	Sowing and fertilizer application	28
4.	Irrigation & drainage equipment and system	30
5.	Crop protection	27
6.	Harvesting and threshing	24
7.	Horticulture and plantation	55
8.	Processing machinery	25
9.	Milling equipment	18
10.	Dairy and animal husbandry equipment	58
11.	Farm transport	14
12.	Storage structures	53

The Ministry of Agriculture, Government of India has established 6 Regional Testing Centres located at Budni, Madhya Pradesh (Central Region), Hissar, Haryana (Northern Region), Ganganagar, Rajasthan (Northern), Assam (Eastern Region), Anantpur, Andhra Pradesh (Southern Region), Tamil Nadu (Southern Region). CFMT&TI, Budni is equipped to undertake testing of tractors, combines and other agricultural machinery. Other Centres, test agricultural machinery and irrigation equipment. These Centres conduct testing and evaluation as per BIS Test Codes.

Steps for improving Mechanization

Rice mechanization, sugarcane mechanization, cotton mechanization, potato mechanization, horticulture mechanization, green house and covered cultivation, drip and micro irrigation are new emerging areas which need attention

Research and Development

Agricultural research and education has been a major consideration in agricultural development in India. The Indian Council of Agricultural Research (ICAR) institutes and state agricultural universities (SAUs) are located in several states.

Two institutes of the ICAR conduct research and development exclusively in the areas of farm machinery and post-harvest engineering and technology. These are the Central Institute of Agricultural Engineering (CIAE), Bhopal and the Central Institute of Post-Harvest Engineering and Technology (CIPHET), Ludhiana.

Research on mechanization is also conducted by commodity institutes (for sugarcane, cotton, rice, fodder and horticulture) and several national institutes (for fish, dairy, dry-land agriculture and others). Most of the state universities have agricultural engineering programmes with agricultural mechanization as a major component. The All India Coordinated Research Projects (AICRPs) are implemented under the aegis of ICAR and these currently include:

- Farm Implements and Machinery,
- Renewable Energy Sources,
- Utilization of Animal Energy,
- Ergonomics and Safety in Agriculture,
- Post-Harvest Technology, and
- Application of Plastics in Agriculture.

All these AICRPs have cooperating centers located in different states so as to cater for the mechanization needs of the different agro-climatic zones. During the XII Plan the Ministry of Agriculture has launched a Sub-Mission on Agricultural Mechanization with following components:

a) Promotion and strengthening of agricultural mechanization through training, testing and demonstration

b) Post-harvest technology and management

c) Financial assistance or procurement subsidy for selected agriculture machinery and equipment

d) Establishment of farm machinery banks for custom hiring by small and marginal farmers

e) Establishing hi-tech and high productive equipment

hub for custom hiring enhancing farm productivity at village level by introducing appropriate farm mechanization in selected villages

f) Creating ownership of appropriate farm equipment among small and marginal farmers in the eastern/ north eastern regions

Efforts in Improving Extension Services

Facilitation of the extension services concerning agricultural technologies in general and agricultural mechanization in particular have been focused on the following areas:

- Provision of institutional arrangements to make the extension system farmer driven and farmer accountable.
- Encouragement of Public Private Partnerships (PPPs).
- Strengthening of Mass Media Support by providing location-specific broadcasts through FM and AM stations of All India Radio and the Doordarshan (DD) National TV Channel.
- Provision of fee-based advisory services by graduates in agri-business development and through the establishment of agri-clinics.
- Operation of Kisan (Farmer) Call Centres through toll-free lines.

Quality of Farm Machinery and Training

The Bureau of Indian Standards (BIS) with its network of centers and laboratories in the country is mandated to ensure quality manufacture and marketing of agricultural and industrial products in the country. The BIS formulates specifications of agricultural machinery and other appliances and prescribes test codes. The Bureau also issues ISI quality certificate marks to the products which meet technical specification as per BIS standards. Standardization and quality of implement manufacturing has been ensured mainly by the Bureau of Indian Standards (BIS) which has formulated more than 540 standards on agricultural machinery.

Credit and Subsidies for Agricultural Machinery

Long- term credit is usually available for the purchase of tractors and farm machines and short -term credit for the purchase of seeds, fertilizer and similar inputs. The Reserve Bank of India has mandated both public and private sector banks to provide 18 per cent of their total credit available to the agriculture sector. Public and private sector banks failing to reach this mandatory level are required to remit the shortfall at a nominal rate to the National Bank for Agriculture and Rural Development (NABARD). This incentive for financial loans is encouraging farmers to purchase tractors and other machines.

Conclusions

There is no doubt that India has achieved considerable progress in the field of agricultural mechanization over the past five decades. The development and dissemination of the mechanization technologies was largely dominated by the private sector–machinery and implement manufacturers and distributors as well as the farmers themselves who were ready to invest in agricultural machinery and implements.

Tractor sales have doubled during last five years while the number of draught animals is declining rapidly. Statistics on other machinery and implements show similar trends. Four wheel tractors and irrigation pumps have dominated the farm power sector in India with much less use of two wheel power tillers compared to other Asian countries. The availability of credit at subsidized rates has been catalytic to the rate at which farmers–especially the small and medium scale ones–were able to procure agricultural machinery and implements. The high level of effective demand for agricultural machinery and equipment led to the creation of a competitive and viable manufacturing industry. Presently little effort has been made to mechanize hill agriculture, where there is tremendous potential of growing horticultural crops, flowers etc. In future this calls for developing appropriate technologies for mechanization.

In order to enforce quality, reliability and safety in the manufacture of agricultural implements, manufacturing of critical components need to be standardized and encouraged for mass production by medium and large scale manufacturers.

The agricultural engineering programmes established in the numerous state agricultural universities and institutes were instrumental for the success of agricultural mechanization in India. The gaps in mechanization namely, lack of State governments policy, slackness of government machinery towards mechanization, lack of cooperative team work among small farmers, need for location specific equipment/machinery, active role of financing agencies and promoting farmers to be participating partners in mechanization rather than being passive observers, may be bridged by aggressive focusing of strong policies by all concerned to provide

a concerted effort to achieve the future goals for future

The critical constraint factors are:

- Reliability and quality of agricultural machinery.
- Availability of products, spare parts and after sales-services in close proximity.
- Availability of Bank credit on terms where currently the farmers have to mortgage both the equipment purchased and his land.
- Lack of effective consumer protection in rural areas for redressel of cases of product problems, and poor after-sales- services, etc.

The future agricultural mechanization technology package therefore may have to:

- Be eco-friendly utilizing land water and bio-resource catering to the varied group of farm holders.
- Facilitate farming operations which are arduous and hazardous.
- Increase productivity and conserve resources through effective utilization of chemical, biological and mechanical inputs.
- Modernize commercial agriculture to facilitate agro-export.

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