Infusion of farm mechanization technologies in Indian agriculture: Progress and Impact

Article · March 2015

DOI: 10.5958/2322-0430.2015.00014.1

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INFUSION OF FARM MECHANIZATION TECHNOLOGIES IN INDIAN AGRICULTURE: PROGRESS AND IMPACT

Mankaran Dhiman * and Jaskaran Dhiman**

ABSTARCT

India has shown remarkable progress in agriculture since independence. The food production scenario has greatly improved. In view of the intensive agriculture especially in the food bowl states (Punjab, Haryana, and western Uttar Pradesh), short window of time available between harvesting of paddy and sowing of wheat, as well as well as labour shortage, the farm mechanization can have a crucial role to play. For making farming globally competitive and checking impairment to natural resources (soil and water) base, a major shift in farm mechanization is required to realize the goal of eco-friendly sustainable agriculture with cost-effective production of quality produce. Appropriate and selective mechanization is needed for production agriculture, post-harvest handling, and value addition using a prudent combine of conventional and renewable energy sources. To devise long term strategies for farm mechanization, it is vital to visualize the needs in view of the prevailing and emerging challenges.

Keywords: Farm mechanization, Indian agriculture, technology infusion
JEL Classification: O12, Q01, Q15, Q16, Q18,

INTRODUCTION

Agriculture plays a vital role in the economic development in India. Since independence, India made a noteworthy progress in agriculture in terms of rapid transformation on the foodgrain front. The Indian Green Revolution, which indeedhas been anexemplary success story of independent India, took roots in the mid sixties. It was ushered in through taking up of higher and balanced use of biological, chemical and mechanical inputs together with the timely government intervention and support. The key elements for the success of this well-orchestrated Green Revolution were: Development of high yielding varieties of wheat and rice; Generation of complimentary production technologies; Efficient technology transfer to farmers; Adequate availability of inputs (irrigation, fertilizers, etc.); Highly responsive and keen peasantry; Pro-agriculture government policies (paddy and wheat procurement at MSP, PDS, etc.). Besides, the infrastructural facilities such as irrigation systems, rural electrification, link roads and storage facilities; Marketing of farm produce and input distribution system; Machinery manufacturing and farm mechanization; Consolidation of land holdings; Institutionalization of farm credit, etc. also led to the success of Green Revolution.

The improvements in agro technology

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including that of farm mechanization in India brought about revolutionary enhancement in agricultural production. From a net importing country, India is nowproducing more than 264 million tons (mt) of food grains. For meeting the food security needs of the country, agricultural productivity and its growth needs to be sustained and further improved.

Farm Mechanization provides the technology to facilitate agricultural growth through efficient use of inputs. It can have a great role to play in the development of agriculture. Mechanization is important from tillage and seed-bed preparation, sowing/ planting, inter-culture, fertilizer application, irrigation, harvesting, to post harvest operations. With newer technologies like zero-tillage, raised bed planting, residue management, precision agriculture, micro-irrigation, mulching, etc., for farming the dependence on farm mechanization has increased. Adoption of mechanization ensures timeliness of agricultural operations reduces cost of production as well as reduces drudgery in carrying out various farm operations. Equipment and implements for various operations like tillage, sowing, irrigation, plant protection and threshing, etc. are generally being used by farmers.

India is in the early stage of development as far as mechanization infusion is concerned. A big leap toward mechanization is expected infuturedue tolabour shortage owing to rural employment guarantee scheme and prevailing pressure to boost productivity (Balachandar, 2014 and Srivastava, 1999). Although, India is the largest manufacturer of tractors in the world, accounting for one-third of world production (Ravi, 2013), the average power availability in the country is lower than many countries (Korea, Japan, US).

The migration of people to urban areas and availability of credit and money arealso main factors in mechanization. The movement of labour away from agriculture has gained momentum in recent years, although the share of workers living off the land still remains at 54.6% of the work force (Ravi, 2013). The farmer population has shrunk by 9 million between 2001 and 2011. In view of the efforts being made to modernize Indian agriculture, mechanization in an important element (Vatsa, 2013). The farm mechanization has been well received world over as one of the central elements of modernization of agriculture. There has been a substantial progress of mechanization in agriculture, however, its spread has been in the most uneven manner. Further, efforts to identify specific farm equipments, implements and machines, for different agro climatic zones, as well as their promotion in the respective zones has been lacking. Looking at farm implements used per 1000 ha of net sown area in the country, the tractor operated machinery is commonly used (Table 1). The Ministry of Agriculture, Government of India is giving a focus to agricultural mechanization including R&D, custom hiring and better technology infusion, through its various schemes. The focus is on increasing the reach of mechanization to the unreached regions and farmers.

Table 1: Number of farm machines per 1000ha net sown area in India

(000'ha^{-1})

Machine	Number	Machine	Number
Manual seed drill/seed drill-cum- fertilizer drill	153.2	Power operated horticultural tools	8.9
Animal drawn leveler	84.8	Drip and sprinkler equipment	8.3
Animal drawn seed-cum-fertilizer drill	36.1	tractor drawn seed-cum-fertilizer drill	7.2
Manually operated plant protection equipment	28.5	Tractor operated disc harrow	6.6
Straw reaper	18.8	Tractor operated levlers	6.2
Forage harvester	18.2	Power operated plant protection equipment	4.3
Tractors	16.7	Potato digger	2.1
Tractor operator cultivator	12.5	Tractor operated rotavator	0.9

Source: Ministry of Agriculture (2012)

Punjab, the agriculturally progressive state, has achieved tremendousgrowth in rice and wheat system where 3.5 million hectares which form 80 percent of total cultivated area is under wheat and 2.8 m ha (68 percent) is under rice. Cropping intensity of the state is 191 percent. This unparalleled achievement has been only possible through mechanization of crop production system. This paper appraises the findings of various researchers on the progress and impact of the infusion of farm mechanization technologies on agriculture. The sale of tractors and power tillers in India has shown exponential increase over the years (Table 2).

Table 2: Sale of tractors and power tillers in India

Year	Tractors (lakh)	Power tillers (000')
2004-05	2.47	17.48
2005-06	2.96	22.3
2006-07	3.53	24.79
2007-08	3.46	26.13
2008-09	3.43	35.29
2009-10	3.94	38.79
2010-11	5.45	55.00
2011-12	6.07	60.00

INFUSION OF TECHNOLOGIES

Tractors

In the mechanization process tractor the common farm vehicle has played a pivotal role and at present there are about 4.50 lakh tractors in the state. The use of tractors and tillers has increased five-fold in the last 40 years (Ravi, 2013). On an average, there is almost one tractor for every 25 acres of land. Now the tractor is available with several features such as air conditioned cabins, ergonomically designed pedals and levers. Tractor performs several functions. All tillage operations are mechanized through tractors. These are also used for the operation of wheat thresher and pumping water through generator in the absence of electricity power supply. Average HP in the state is almost 3.7 KW per ha.

In India, tractor have been used for performing operations using tillage equipment like rotavator and spading machines (22.78 percent of total area) and sowing (21.3 percent of total area) and is also used for running other equipments like laser land leveler. The share of farm workers and draught animals has come down from 63.5 percent in 1971-72 to 13.6 percent in 2009-10, whereas the share of tractors, power tillers, and motors has gone up from 36.5 to 86.3 percent during the same period (Ravi, 2013). The contribution of tractors has increased from 7.5 percent in 1971 to over 51 percent in 2010-11(Singh*a et al.,* 2012). The increasing cost of labour and upkeep of draught animals also led to more adoption of tractors for farm operations.

Tractors are available from 18 to 70 HP range. The market has been moving toward bigger tractors during the past few years. In 2005, 4-5 percent of the total industry was of higher HP tractors (48HP). In 2013-14, however, the domestic tractor industry volumewas in the tune of 6.35 lakh of which 48HP tractors accounted for16 percent (Balachandar, 2014). In view of shortage of labour, the need for tractor mechanization arises. According to Sharma (1998) the projected demand for tractors in India is 22.58 lakh in 2024-25. Singh and Jain (1981) estimated that agricultural productivity and labour force were important econometric variables determining the demand of tractors in Punjab. Chatha and Grewal (1991) revealed that demand for tractors in Punjab would be 5.60 lakh in 2030-31 and indicated that by 2010-11 there will be saturation point as far as the number of tractors is concerned and that further demand of 25-32 thousand tractors will be due to replacement reasons. With the recommendation of rotavator, the higher HP tractors will play a vital role. Thetractors with advanced features but with affordable price range are needed. The normative demand of tractors in Punjab is higher than the prevailing tractor use. In Punjab, the farmers are buying tractor as their status symbol though its field use (264 h) is far below the normal annual requirement (1000 h).

The big manufacturers of tractors and

pumpsets have their dealers in big towns in the country. Almost in every town there are a few manufacturers making different types of machines and implements. There aretractor manufactures in the Punjab with annual production capacity of one lakh tractors. In spite of good manufacturing base for production of different types of farm machinery, their availability in many places is not very satisfactory. Subsidies on different types of farm machines are available for different categories of farmers under the micro-management schemes of the state governments.

Seed-cum-fertilizer drills

Several types of tractor-operated drills and seed planters with fertilizer attachments have been developed and introduced in India in the late sixties. Animal and tractor operated seed planters were developed and made availableto farmers. During the seventies R&D work was devoted to evolving new models, fine tuning the seed metering mechanisms, power transmission systems, frame designs, and developing suitable types of furrow openers.The Punjab Government gave a subsidy of 33 percent to all farmers buying drills. Evaluation and testing of various types of drills and planters under varying soil and field conditions also intensified during the seventies. A need-based target for introducing about 50,000 improved drills was set in 1968-69. At present about 1.8 lakhs of seed-cum-fertilizer drills are being used by the Punjab farmers. Drills in size rangeof 7 to 15 rows for tractors are available. The most common seed-metering device in drills is the external fluted-feed roller and that on planters is the inclined or vertical plate with cells.

Although this method of wheat seeding using zero-till seed-cum -ferti drill is becoming very popular in Haryana and Punjab states but it not popular in U. P. particularly in central parts (Singh *et al*., 2014). According to Singh *et al*. (2014) wheat crop can be sown 10-15 days earlier as compared to conventional method of sowing. This will result in timely sowing of wheat crop and increase in yield. Further, in zero-till ferti seed drill system, the average cost of irrigation was ₹2592 per ha which was ₹667.5 per ha lesser in comparison to conventional system and gives 21 percent saving. The zero tillage sowing was more economical (79 percent) in comparison to conventional methods of sowing. It was observed that zero-till ferti seed-drill system was found an acceptable machine by the farmers of district Ambedkar Nagar (UP) because the zero-till ferti seed-drill system gave highest benefit cost ratio (1.76) in comparison to conventional system. The machine has been discussed from various angles (Chauhan and Kumar, 1992).

The Indian drills and planters place fertilizer in a band usually on one side of the seed at the same depth or deeper. Agronomic research shows fertilizer placement in a band about 2.5 cm to the side and about 2.5 cm deeper than the seed leads to about 8 to 10 percent increase in yield of cereal crops. Indian Standards Institution (ISI) formulated several standards relevant to the seeding equipment. The manufacturers of the state considerably improved equipment quality and started using jigs and fixtures for making its components (Guruswamy, 1985).

Threshers

An indigenous thresher called 'Ludhiana Thresher' was developed during the mid-l950s, by Mr S.K. Paul (farm engineer) and Mr . Sunder Singh (an innovative small-scale manufacturer of Ludhiana), which was the first indigenous power thresher to be commercialized and acknowledged., Indian Council of Agricultural Research (ICAR) recognized the inventors of the Ludhiana thresherin 1957. It was capable of threshing and cleaning besides facilitating bagging.This followed suit as it was followed by the low-cost drummythreshers, better-designed Naini or Sherpur threshers, and low power Syndicator/Toka threshers capable of handling even moist wheat.

Recently, bulk automatic feeding with auto-

reverse, and multi-crop threshers have come. Punjab State has reached acompletely mechanized wheat threshing level. The engineers are now focusing on precise aspects like reducing energy consumption, safety, quality control, and standardization. The threshers are being manufactured on a small scale industry level. Ancillary units produce components required by thresher manufacturers. The PAU designed and developed multi crop thresherbased on conventional rasp-bar design. It can thresh several crops except groundnut. However, peoplerequire bruised straw for feeding to cattle. Thus, a new design used a tractor-operated rasp-bar thresher to yield better bruised straw. At present about 8 lakh threshers are being used by the farmers of the state. The infusion of this technology has helped farmers to market their wheat produce timely.

Threshers have been designed for different crops such as wheat, maize, groundnut, cowpea, mungbean, etc. Threshers often lead to some accidents causing varying level of injuries. It is estimated that every year in Haryana, Punjab and Uttar Pradesh alone there may be 5000 to 10,000 deaths 15,000 to 20,000 amputations and 1.5 to 2.0 lakh serious injuries due to farm activities (Mohan and Patel, 1992). Among these, threshing machines are responsible for a significant number of serious injuries. Kumar *et al*. (2002) suggested a cost effective, improved design for safe operation ofthreshers based on ergonomic principles. Threshers have been designed to suit the needs of small farmers(Azouma *et al*., 2009).

Combine harvesters

The combine harvester, or simply combine, is a machine that harvests cereal crops. The name is due to its combining three operations (reaping, threshing, and winnowing) of harvesting into a single one (Quick and Wesley,1978). Combining is found to be the cheapest method of harvesting and threshing paddy and wheat (Alam, 2005). There are about 30 manufacturers fabricating combines. Combine harvester machines for harvesting of rice, wheat, maize, green gram, soybean, etc. are available. Tractor mounted, tractor driven, self-propelled combines with 8-14feet headers have been manufactured.

In Punjab, 91 and 82 percent area under paddy and wheat is harvested with combine harvesters.Currently, there are nearly 15,000 harvesters available in the state. About 90-95 percent combine harvesters are operated on custom hiring basis, which considerably reduce the cost and availability of these costly machines, which cannot be otherwise afforded especially by the small farmers. The major international companies like CLAAS and John Deere haveset-up their manufacturing base in the state. Punjab is considered to be hub of manufactures of combine harvesters and supplies this machinery to the rest of the country. the limitation is that the combine harvesters do not handle crop residue and create management problem. Track type small harvesters are also manufactured, which can be operating in water logged and wet lands.

Laser land leveler

The laser land levelling technology is used to level bigger fields. Land leveling is an important operation for good agronomic, soil and crop management practices (Anuraja*et al*., 2013). Cook and Peikert (1960) reported that a significant (20-25 percent) quantity of irrigation water was lost during its application due to poor farm designing and unevenness of the fields. The levelled fields have better water use efficiency. Aggarwal *et al.* (2010) assessed water saving in different crops (maize, wheat, cotton, paddy, berseem, pea, potato) through precision land leveling and reported a water saving in the range of 22-33 percent (average 26. 64 percent). Reporting that 10, 25, 50, 75 and 100 percent adoption of laser land leveller can result in saving of 1.46, 3.66, 7.33, 10.99 and 14.65 lakh haM of water, they recommended the use of laser land leveller to save water in Punjab where water table is depletion is a cause of concern.

Several researchers have conducted field experiments to evaluate the performance of

laser landleveler for land leveling and grading operations to determine its effect on water requirements and yield of selected crops. In the case of paddy crop, land leveling by laser guided land leveler resulted in much lesser variations in height of standing water as a result of which 16.67 percent water saving was observed per irrigation. Crop yields were higher in case of fields laser leveled and graded fields. However, differences were significant in the case of paddy and pigeon pea crop only (Chaudhuri *et al*., 2007).

In another report (Aryal*et al.,* 2011) laser leveling in rice fields reduced irrigation time by 47-69 h per ha per season and improved yield by approximately 7 percent compared with traditionally leveled fields. In wheat, irrigation time was reduced by 10-12 h per ha per season and yield increased by 6.7 percent in Haryana and 8.8% in Punjab by adopting laser leveling. The monetary benefits of laser leveller in terms of increased yields of paddy and wheat was equivalent to USD 138 per ha per year. This shows that the use of laser leveler has become economically accessible, even to small holders and resource-poor farmers. The technology was recommended in 2006 as it ensures better water distribution efficiency, provides option for providing slope, ensures better crop stand/ yield. The infusion of this scale neutral technology (not biased towards large farmers) has recently been picking up as the number of laser levelers has been increasing exponentially in the Punjab starting with merely three in 2006 to more than 7200 at present. It has levelled around 15,000 ha area in Punjab (Table 3). Cooperative Societies are also helping farmers to avail laser land levler.

Table 3: Area levelled using laser land levelers in Punjab

Year	Area laser levelled (ha)
2005	8
2006	150
2007	550
2008	1000
2009	2000
2010	4100
2011	6250
2012	9370
2013	11580
2014	15000

About 32 percent of the cropped area has been laser levelled in the state. Besides leading to water saving, the laser levelling technique is beneficial in many ways. Nearly 20-25% of irrigation water is lost due to unevenness of the fields leading to non-uniformity in germination, poor crop stand, more weeds and uneven crop maturity affecting yield and quality of produce. Proper land levelling is needed for optimum water and nutrient use efficiency, better crop establishment, saving in time for applying irrigation and ultimately more productivity. Number of manufacturers in the state are producing and selling the machines in Punjab and also in adjoining states.

Tools and techniques for precision farming

Rapid socio-economic changes in some developing countries, including India, are creating new scopes for application of precision agriculture (Mondal and Basu, 2009). As far as precision farming technology development and infusion is concerned**,** India is yet to catch up with the developments made in advanced countries (Mondal and Tewari, 2007). Some work on this front has been initiated. Various precision agriculture tools like 'grain yield monitor' and 'moisture sensor'fitted on indigenous combine harvesters are being evaluatedthrough online data collection. Efforts are underway to modify 'tractor mounted soil sensor' to appraiseelectrical conductivity (EC) and compaction of soil at the same time. The CSIO, Chandigarh has developed tractor mounted *soil EC mapper*.Tractor operated *pH monitoring system* has been developed.The tractor fitted GPS Navigator is being evaluated to guide the tractor and to analyze the effect on missing and overlapping during different tractor operations. A ground-based i*ntegrated system* was to measure real-time crop conditions including Normalized Difference Vegetation Index (NDVI), real time images,

biomass, etc. has been developed.The prototype of variable rate applicator for fertilizershas been developed to reduce the common problems of over and under fertilizer application. High resolution multi spectral satellite data of different sensors i.e World View (WV-02), Quickbird (QB02), Geoeye and IKONOS-02 is being used to establish relationships with soil and crop parameters for selected sites of Punjab and Harayana. Soil texture analysis and spatial variability maps generated in terms of sand, silt and clay percentage by using satellite data are useful. Such precision farming technologies using interdisciplinary efforts and involving ICT will help rationalize the use of inputs.

Infusion of farm mechanization technologies through Custom hiring

Indian agriculture, for that matter Punjab agriculture, is largely dominated by small holdings (Singh *et al*., 2013).Small holdings have their intrinsic problems. The ownership of machinery is mostly determined by the economic viability. The custom-hiring system can be greatly helpful (Dhillon and Sidhu,1987 and Pandey, 2000). Custom hiring service of farm machinery was first introduced in pre-partition Indian agriculture in 1912 when a 30-inch (diameter) steam thresher was used for custom hiring in Layallpur district. These machines were taken to about 10 different places working for 2 or 3 days at each place. The users were charged half rate only i.e. 2 anna a maund. The output of this thresher was about17 kg per h. Organizedefforts to promote multi farm use of agricultural machinery was made in mid 1960's when Agro-Industries Corporations (AIC) were established in the states. The AICs acted as facilitators of farm mechanization. The AICs in most states setup Agricultural Machinery Service Centers (AMSCs) to provide custom hiring and servicing facilities to farmers. These centres were run on no profit no loss basis. From 1967 these centers also supplied other machines like pump sets, tractors, power threshers and power tiller on hire purchase basis rather than on custom hiring. The custom hiring system is better for the smaller farmers for availing non-farm employment opportunities.The government has also developed the Primary Agricultural Cooperative Societies as Agro-Service Centres for such services. This would particularly be beneficial to the small farmers to cut down their cost of production, enhance productivity and increase their net farm income.

The establishment of Agro Machinery Service Centres (AMSCs) at various Primary Agricultural Cooperative Societies (PACSs) was initiated during the early-2000s in Punjab. These AMSCs purchased heavy farm machinery such as tractors, trolleys, laser levellers, etc. out of their own savings, institutional loans and subsidy support from the government to provide timely services to the farmers, especially small and marginal farmers, at reasonable rates. These AMSCs have successfully catered to the farmers' needs, thereby reducing their investment burdens, and costs of farm operations with subsequent improving of economic viability of these farms.

Table 4: Number of operational holdings by size group

('000)

Farm category	1990-91				2004-05			
	India	Punjab	India	Punjab	India	Punjab	India	Punjab
Marginal	63389	59.44	297	26.48	83694	64.77	135	13.45
Small	20092	18.84	204	18.25	23929	18.52	184	18.33
Semi- Medium	13923	13.06	288	25.85	14127	10.93	319	31.77
Medium	7580	7.11	261	23.41	6375	4.93	295	29.38
Large	1654	1.55	67	6.01	1095	0.85	71	7.07
All Holdings	106637	100	1117	100	129222	100	1004	100

Source: Department of Agriculture and Cooperation, Agricultural Census Division (c.f. Singh et al., 2013)

Impact of mechanization

A number of studies have been attempted in different parts of the country to assess the impact of farm mechanization. The impact has been viewed in relation to agricultural production and productivity, enhancement of cropping intensity, employment generation, conservation of natural resources, etc.

Availability of mechanical power and improved tools and equipment has enabled the food bowl states of Punjab, Haryana and western Uttar Pradesh to achieve high level of land productivity (Goyal *et al.,* 2014) and the same should happen to other states. A positive relationship exists between farm power availability and agricultural productivity (Singh, 2001).According to Gajri *et al.* (2002), farm mechanization has enhanced the area under crop cultivation and thereby contributed toward increased productivity mainly because of the precision with which crop agronomical operations can be accomplished.

Mechanization of farm operations has greatly helped in reducing the labour requirement, drudgery and cost of cultivation and saving farmers from vagaries of weather. It has also led to an enhancement in cropping intensity. The tractorization, which is considered as back bone of mechanization, has played a key role in making the Green Revolution a grand success in India (Bector*et al.,* 2008). Despite some divergence that the tractorization displaces bullock, labour and retrenchment of manpower in the labour intensive country like ours, the farm mechanization or use of tractors (4.5 lakh in Punjab) has contributed significantly to the growth of Indian agriculture (Singha *et al.,* 2012) it enhances the agricultural GDP both in the long and short run. According to Verma (2005) tractor farms yield more than the non-tractor farms in India, especially of the commercial crops like sugarcane and potato.

Prioritization and future outlook for mechanization

In view of the intensive agriculture especially in Punjab, Haryana, and western Uttar Pradesh, short window of time available between harvesting of a crop and sowing of the next, as well as well as labour shortage, the farm mechanization is critically important. There are estimates that farm mechanization in India is set to enter a new phase to meet the growing demand for food grains and other food and non-food commodities(Goyal *et al.,* 2014) and the process needs to be re-looked and re-engineered so as to effectively include small and marginal farmers (Aggarwal,1983). According to Bakshi (2013), Indian agriculture is undergoing a heavy stress as average land holdings is decreasing day by day. The acreage has remained at 140 million hectares since 40 years but the number of farmers has increased from 7 crore to 14 crore. We are adding one crore farmers every five years. With smaller land at disposal, there is a decrease in farmers' capacity to invest in land.

For making farmers globally competitive and checking damage to natural resources (soil and water), a major shift in farm mechanization is required to realize the goal of eco-friendly sustainable agriculture with low cost of production and high quality produce. Appropriate and selective mechanization is needed for production agriculture, post harvest handling, and value addition using a proper combine of conventional and renewable energy sources. To devise long term strategies for farm mechanization, it is vital to visualize the needs in view of the prevailing challenges (Goyal *et al*., 2014). The following points are relevant in this regard:

- Power farming should be adequately adopted fortimeliness and precision of field operations, maximizing use efficiencies of agrochemical inputs(fertilizers, seeds, etc.),for natural resource (water and soil) conservation and environment (Joshi, 1998, Srivastava, 2002 and Rijk, 1989).
- Due focus should be given to precision equipment for proper placement of inputs (Gajri *et al.,* 2002) for precision farming. Tractor mounted sensor based nutrient

application and yield monitoring for combine harvester need to be developed for precision agriculture.

- Sub-soilers and equipment for deep tillage for breaking hard pan and managing with perennial weeds should be introduced.
- Conservation tillage technologies (zero till drills, strip till drills, roto drills, tillage machines, spading machines, raised bed planters, ridger seeder, etc.) should be promoted priority (Peter, 1993).
- Low cost multi-task and multi-crop farm machinery needs to be developed and promoted among marginal and small farmers.
- Mechanization of sowing and harvesting of major crops, collection and management of residue of paddy and other crops and mulching should receive priority.
- There is need to develop and promote machines/equipment for sugarcane harvesting, cotton picking and vegetable harvesting. Mechanization solutions for paddy, sugarcane, cotton, potato, horticultural crops, and green house protected cultivation, etc. needs attention of engineers and industries for their development, production and marketing.
- For mechanization of horticultural crops, machines like pit makers, sapling planters, mulch layers, orchard sprayers, fruit harvesters, vegetable grafting machine, etc. need to be identified, designed/ introduced and popularized.
- Design, import, evaluation and promotion of pneumatic planters and sprayers should receive focus.
- Design of green house with environmental control mechanized cultivation and product-handling technology package will assume greater importance.
- Mechanization in hill agriculture, where there is tremendous potential of growing horticultural crops, flowers etc. exist, needs to be focused.
- In view of depleting water resource and increasing demand for irrigation water, efforts are needed for strengthening research on drip, sprinkler and micro-sprinkler systems to economize water use and improving its use efficiency.
- Electronic procedures/devices for identifying gaps and counting seeds/ seedlings in planters/transplanters need to be introduced (Singh and Bhardwaj, 1985).
- Use of information and communication technology(ICT) and computer concepts for the designing, manufacturing and management of farm machinery.
- The public-private partnership (PPP) needs to be encouraged to give a boost to farm mechanization
- The present trend in agricultural mechanization is for high capacity machines to be used on custom hiring and for contractual field operations.
- The future mechanization strategy may have to be based on agro-ecological diversity and economic disparity of the farmers. Combine harvesters incorporating straw/crop residue management options need to be developed.

CONCLUSIONS

For meeting the food security needs of the country, agricultural productivity and its growth need to be further improved. This requires among other efforts, strengthening of farm mechanization. Viewed over the years, there has been a substantial progress; however, its spread has been uneven. Further, efforts to identify specific farm equipment, implements and machines, for different agro climatic zones, as well as their promotion has been lacking. The tractor operated machinery is commonly used. The sale of tractors and power tillers in India has shown exponential increase over the years. All tillage operations, running of wheat thresher and water pumps (in the absence of electricity power) are mechanized through tractors. With the recommendation of rotavator, the higher HP

tractors will play a role. Sowing drills and machines capable of threshing and cleaning different crop produce besides facilitating bagging are in practice. Combine harvester machines for harvesting of rice, wheat, maize, green gram, soybean, etc. are available. Tractor mounted, tractor driven, self-propelled combines with 8-14feet headers have been manufactured. Land leveling technology ensures better water distribution efficiency, provides option for providing slope, and ensures better crop stand/yield. The infusion of this scale neutral technology has recently been picking up exponentially. Rapid socio-economic changes in India, are creating new scopes for application of precision agriculture and some sensor based equipment is being standardized for site application of nutrients and adjusting soil moisture. Such precision farming technologies using interdisciplinary efforts and involving ICT will help rationalize the use of inputs. Our contemporary agriculture is largely dominated by small holdings having their intrinsic problems. A number of studies have been attempted in different parts of the country to assess the impact of farm mechanization. The impact has been viewed in relation to agricultural production and productivity, enhancement of cropping intensity, employment generation, conservation of natural resources, etc. Mechanization of farm operations has greatly helped in reducing the labour requirement, drudgery and cost of cultivation and saving farmers from vagaries of weather. For making farmers globally competitive and checking damage to natural resources (soil and water), a major shift in farm mechanization is required to realize the goal of eco-friendly sustainable agriculture with low cost of production and high quality produce. Appropriate and selective mechanization is needed for production agriculture, post-harvest handling, and value addition using a proper combine of conventional and renewable energy sources. To devise long term strategies for farm mechanization, it is vital to visualize the needs in view of the prevailing challenges. Subsidies on different types of farm machines are available for different categories of farmers under the micro-management schemes of the state governments. The Government of India is giving a thrust to agricultural mechanization including R&D, custom hiring and better technology infusion, through its various schemes. The focus is on increasing the reach of mechanization to the unreached regions and farmers.

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Received: January 20, 2015
Accepted: February