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This is the 162th issue since its maiden isue in the Spring of 1971

EDITORIAL

To all readers, a Very Happy New Year, 2015. As time passes fast, this is the fifteenth New Year in 21st century. At present, heated discussion about multinational trade liberalization, especially for agricultural products has been advancing in the world. Japan has overwhelmingly many small farmers as compared to the western world, and it is difficult to compete for the food prices in international competition. Almost 70 % of farmland in Japan is located in semi-mountainous areas, and it is not only difficult but will cost huge money to make a large working area. Especially for rice paddy, it is more difficult to make a large working area since it needs a level field. Just upsizing of machinery is not effective for Japan to improve labor productivity. Under such a situation in Japan, same as in EU, research and development of small agricultural robot have been carried out. There are many farmers engaging in agriculture in semi-mountainous areas in the world. I think the development of new small machinery such as agricultural robots would help such farmers immensely.

The world population, which exceeded 7 billion now, is increasing in number steadily to 9 billion. We have to increase the output of food production with limited resources that we have. In order to do that, widening the use of agricultural machinery is the most important task to increase the labor productivity as well as the land productivity. Rural areas of Japan are becoming aging societies and the labor force there is rapidly decreasing. And this phenomenon is occurring not only in Japan but also in China and in other parts of the world. Younger generation hates agriculture and moves to cities. At present, urban population ratio of the world is about 50 %. It is estimated to be 70 % at the time when world population will become 9 billion. We must increase the output of food production with a fewer labor force of rural areas. It is clear that agricultural mechanization is the most important task to address this situation.

Daily news tells about terrorism, war and riot. It cannot be said that the current global society is peaceful. In order to live in the constricted earth together, realization of peaceful society is the most necessary for all human beings. There is a research report telling us that the total assets of top 85 of the world billionaires equal those of 3.5 billion poor people. As long as we have such a large economic gap in the narrow earth, realization of peaceful society would be difficult.

Publication of AMA was started for the purpose of promoting agricultural mechanization of small farmers around the world with appropriate technology and by making the technological connections together for farmers to be richer by themselves. The AMA has been published with the hope that worldwide experts of agricultural machinery would increase development efficiency by connecting each other. However, the actual gap has been widening for more than 40 years since 1971. Human beings are a part of the organism system and they have to live in harmony with the non-human life system. Harmonization of the life system will be agriculture in the broad sense. This harmonization brings food, fiber, timber, medicine, biomass energy, beautiful environment, etc. to everyone. Moreover, most important thing is a mental state which human beings acquire by working on a life system through agriculture. I think it has been changing the human by creating a culture over a long period of history. Agricultural machinery is also the one for creating harmonization. I wish that the agricultural machinery will keep serving for making more beautiful harmony in the future.

This year also, I, together with everyone would like to help in improving the status of the farmers all over the world through a new vision of agricultural mechanization.

Yoshisuke Kishida
Chief Editor

January, 2015

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Development of a Self-Propelled Jute Seed Drill Cum Rural Load Carrier

by

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Abstract

Poor economic conditions, small land holdings, and shortage of labors are major problem in jute mechanization, resulting in delayed planting of jute. This research developed and evaluated the performance of a self propelled jute seed drill cum Rural Load Carrier (RLC) for eastern Indian farmers. Jute seed drill suitable for sowing operation in local farms, and a rural load carrier for public and goods transport in rural areas. The RLC consists of the main frame, metering mechanism (MM), furrow opener unit, power transmission, and the carrier frame. A 3.94 kW diesel engine was used as a power source. The coefficient of non-uniformity (1-Uc) varies between 0.22 and 0.29 with standard deviation (SD) of 0.024 for the metering mechanism (MM 2) in jute seed drill. The field performance evaluation was done at the speed of 2.1 km/h. It was observed that the average field capacity and field efficiency were 0.28 ha/h and 69 %, respectively. Fuel consumption varied between 4.8 and 5.3 l/ha. During the evaluation no damaged seeds were observed. The mean emergence time for jute seed was 7.3 and 7.5 days for seed drill sown and conventional sown method respectively. The performance test established that the machine could be used economically.

Keywords: Jute, self propelled Jute Seed drill, Coefficient of uniformity, Metering mechanism, Rural Load Carrier

Introduction

Jute (corchorus sp) is the cheapest vegetable fiber procured from the bast or skin of the plant's stem and the second most important vegetable fiber after cotton, in terms of usage, global production, availability and consumption. India is the largest jute producing and processing country in the world. Jute provides employment to 40 million farmers and 0.2 million-factory workers in country. In India cultivation area of jute crop is 0.91 million ha and annual production of raw jute is 11.82 million bales of 180 kg each with average productivity of 2.01 tones ha^{-1} in 2010 (Anonymous, 2012,). It is a rainy season crop and hence sown from April to May according to rainfall and type of land, and harvested between July to September. Improved methods of cultivation increases jute fiber yield and reduces cost of production in farmer's field. The human labour cost is largest component in cultivation for jute crop. Currently, due to industrial growth and government employments scheme, labour shortage is a major constraint in jute production in the country, especially during the peak cultivation times. Most of the jute cultivators are small and medium farmer and their farms operations are not mechanized, including planting. Hence weeding and pesticide spraying are serious problem due to scattered germination and higher planting density (Rahman and Khan, 2012). Weeding and thinning takes 45-50 % cost of production. If it is not done at proper time; the whole crop is adversely affected (Olubunmi, et al 2009). No weeding tool and machinery can be operated after the broadcasted seeds germination/germinate, this increases the cost of production and decrease the yield and quality. On the other side, jute seed drilling provides a more uniform depth, reduced seeding rate, more uniform emergence providing much needed advantage over manual practices.

Traditionally Jute crop is sown followed by the first rainfall of the season, usually broadcasting is followed by levelling. Poor soil to seed contact, uneven planting depths (some seed too shallow for proper emergence of permanent root systems, and other seed too deep for germination), and often, poor plant distribution are found to be common in broadcasting system of jute planting and are major disadvantages of this method. Broadcast of jute seed is successful up to some extent, when soil and seed bed conditions are optimal, and rainfall or irrigation follows the agricultural operations such as broadcasting, harrowing and leveling. Earlier development of manual drill for small seeds was also not accepted by the farmers due to strenuous walking postures. In manual jute seed drill operation, the subject had an approximate inclination of 600 and 530 with horizontal while walking backwards and pulling from front respectively. Draft requirement of manual drill was 402 N. Two men were required at a time to operate the four row drill in jute sowing. Low field capacity (0.094 ha/h) and maximum period of operation at a time was only 14 min. These were major hurdle in operating manual seed drill. Field performance and germination of jute crops by this drill was not found satisfactory. One major reason of poor germination was imperfect metering mechanism.

The importance of transport in the rural setting has been recognized by the Government of India as a basic means for sustaining agricultural growth and rural economy (Gilbert-Miguet, 2011). In rural areas, the poor farmers are mainly dependent for their livelihood on their ability to produce and market agricultural products in nearest cities. Besides this, six percent of the Eastern India rural households have to walk from one to two hours to the nearest all-season road, and another two percent have to spend about half day. Improving the availability of rural transport could positively impact on the livelihood in such rural areas. This is possible only with the help of cost effectiveness, and rural load carrier cum public passenger transport vehicle.

Poor economic conditions, small land holdings, and shortage of labors are major problem in jute mechanization, resulting in delayed planting of jute in rural eastern India. Poor public transportation facility was also one of the major constraints in rural livelihood. The objective of the current study was to design and develop a low cost jute drill cum Rural Load Carrier (RLC). The effects of the developed seed drill on plant emergence were examined and obtained yield was compared to the yield obtained from the conventional method of sowing.

Materials and Methods

The design and development of jute seed drill and RLC was done on the basis of mechanical requirements and agronomic practices. The agronomic requirements were related to the seed rate, planting depth, row spacing, and soil-moisture management. Similarly the mechanical design requirements related to power transmission, traction, soil compaction, depth control, seed metering, and maneuverability. Each requirement was discussed with the agronomist, research scientists and farmers to determine the design specifications that would best meet the West Bengal farmer's practices. The resulting drill was fabricated in the workshop and tested in the research field of Agricultural and Food Engineering Department of IIT Kharagpur, West Bengal, India.

Jute Seed

The jute seed drill was tested in laboratory to examine the performance of the metering mechanism and the planting mechanism. Jute seeds of 2.54 g/1000 numbers were used for this study. Mean dimensions of selected jute seeds, popular in the area, were 2.21 × 1.32 × 1.08 mm and the angle of repose was 27.9º.

Mechanical Design Specifications of Designed Jute Drill

The main parts of developed seed drill were seed hopper, ground wheel, metering mechanism (MM), frame, and furrow opener.

Metering Mechanism: For designing the metering mechanisms' cells size and shape, four different types of mechanism were developed and evaluated in laboratory. The MM moves under an arrangement called cut off, this allows only those seeds which could be accommodated in the cells. Cut-off mechanism brushed out excess seeds from the cells of the feeding mechanism. For brushed excess jute seed a square shape pad of size (80 × 50 × 5 mm) was placed around each metering mechanism, the pad had a square cut of (30 × 10 × 5 mm) in centre. Seed rate of the seed drill was controlled by the square cut of the pad.

Furrow Opener and Depth Control: Narrow shovel type furrow opener was selected to provide good penetration under a wide range of soil conditions form a narrow slot for optimum and splitting placement of jute seeds into row. The openers were attached to a rigid tool bar so that it moved up and down as a unit to provide uniform depth control for all openers. The furrow opener with width of 52 mm, shear width of 35 mm, boot length of 210 mm was selected. Rack angle and boot wedge angle of 40º and 90º respectively were considered for furrow opener (Darmora and Pandey, 1995). Pipes of 20 mm diameter were welded with small straight pointed shovels and connected to the seed box through appropriate PVC tubes.

Maneuverability: Jute seed drill had to operate in a small field with minimum disturbance to the surrounding plot area. This required the ability to readily start and stop, and ability to turn within a short distance (turning circle radius was 1,450 mm) and to be controlled with a high degree of accuracy. These requirements were fulfilled by a self propelled concept of machine with minimized size and placement of the operator close to the working area.

Traction and Seed Firming: For field conditions of jute cultivation two rear wheels had to serve as traction wheels as well as accomplish seed firming. Hence all of the drill's weight was utilized in developing tractive effort. In addition, the wheels should be as narrow as possible to minimize the compaction effect on the prepared surface. It should also be able to flex over uneven ground for good traction and seed firming in an unprepared seed bed. The self propelled unit had two pneumatic traction wheels (152.4-304.8 mm) and one steering wheel (82.55-406.4 mm) in rear and front side respectively.

Developed Seed Drill

Common feed shaft driven by the ground wheels were located on both sides of the seed drill. The drive to the seed metering was powered by a ground driven steel wheel with diameter of 440 mm. MM was mounted on the main shaft of 25 mm diameter and carries the seed from hopper. The metering mechanism cells were designed to receive and accommodate 1 or 2 seeds from the cone shape hopper. **Fig. 1** shows an isometric view of eight-furrow jute drill with cone shape hopper of 1.5 mm GI sheet and 1.8 liter size, designed and manufactured, and mounted in groups of equal distance at rear side of the machine. The Seeds were dropped from metering mechanism to the furrow opener through PVC pipe. The location of seed in hopper and MM minimized the drop tube angle and height of each furrow openers.

Development of Rural Load Carrier

Load carrier for transportation of agricultural produce and people in rural area was developed. This load carrier was developed by using diesel engine of 3.94 kW (5.3 hp), old two wheeled bike frame, power tiller wheels, wooden panel and locally available materials. Power tiller pneumatic wheel was selected for field and transportation operations. Two speed transmissions system was designed for field and

Fig. 1 Isometric view of eight-furrow jute drill

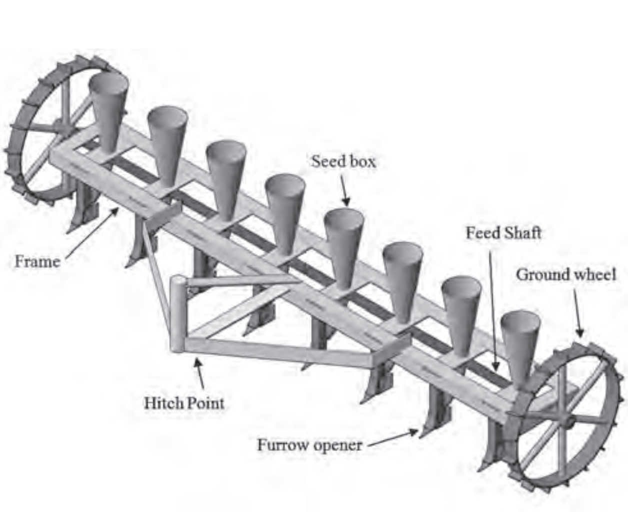
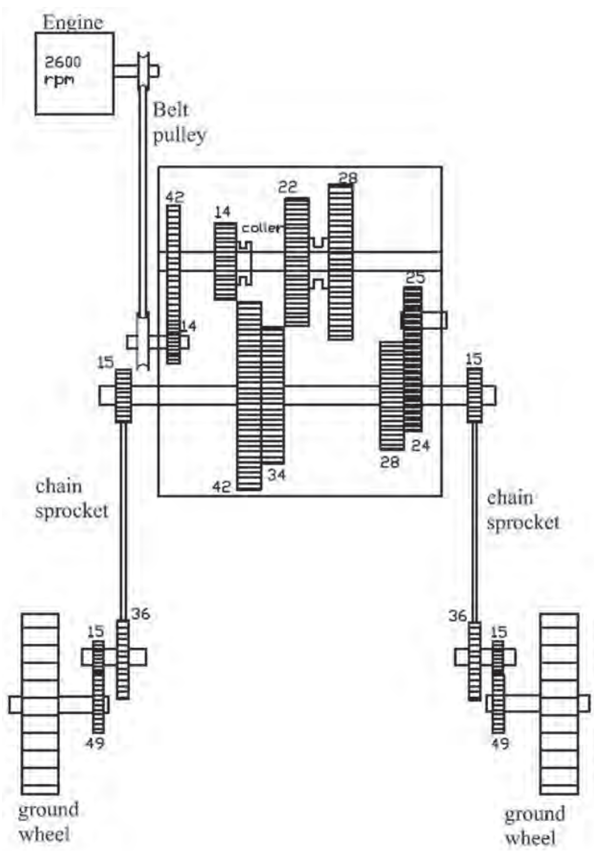


Fig. 2 Layout of power transmission system in neutral position for self propelled jute seed drill cum RLC



transportation on rural road. The power was transmitted from the engine to clutch by using two belts of size B-58. The speed reduction unit constitutes the drive wheels shaft through the spur gears and chain-sprocket combination. Layout of power transmission in neutral position for self propelled unit is shown in **Fig. 2**. The digits indicate the no. of teeth on the gear and chain sprocket. Theoretical speed for field operation and rural transportation were from 1.9 and 8.3 km/h respectively. The loading spring was used to keep the chain in constant contact with the teeth for continuous power transmission and reduced slippage. The cost of this RLC and jute seed was $ 400 and $ 100 respectively.

Experimental Setup for Metering Mechanism Testing

The sticky belt test stand was used and tests were carried out to investigate the uniformity of jute seed discharge using Coefficient of uniformity (Uc) and Coefficient of variation (CV) for four different metering mechanism. The seeds on a 5 m test section at the middle of the belt were counted. The belt section was further divided into twenty intervals of 0.25 m long and the seeds were counted on 20 samples of 25 × 25 mm size white colour frame. For each metering unit under study, total of 60 samples were collected in test rig runs. The number of seeds in each frame was counted. The total number of seeds on the 5 m test distance was also counted. The Uc and CV were determined using the methodology described by Maleki el at. (2006).

A sticky belt test stand was used to examine spacing of jute seeds. A greased belt was used as a substrate to verified seed spacing information. (Kachman and Smith, 1995). Sufficient white grease was added to the top surface of the belt to capture the seed as it was released from the drill with minimum rolling or bouncing on the belt surface. A common unit was used in all treatments. Jute seed drill unit was positioned over the sticky belt as shown in **Fig. 3**. The speeds on the sticky belt were set at a simulated travelling speed between 15-50 m min^{-1} for jute drills. The whole unit was stopped as soon as the discharge seed band reached the end of the test rig.

Coefficient of Variation and Uniformity

The CV is widely used to evaluate seed and granular fertiliser applicators (ASAE S341.3, 1998). Researchers' experience showed that the CV fails to compare drills performance with mostly similar efficiency. Therefore, the new index designated as Uc based on least absolute deviations, developed by Maleki et al. (2006), was used for seed spacing evaluation. Uc is less sensitive to outliers and more accurate for evaluation of seed drills. The value of the Uc, when approaches one, the metering unit performance approaches perfection.

Field Performance Evaluation

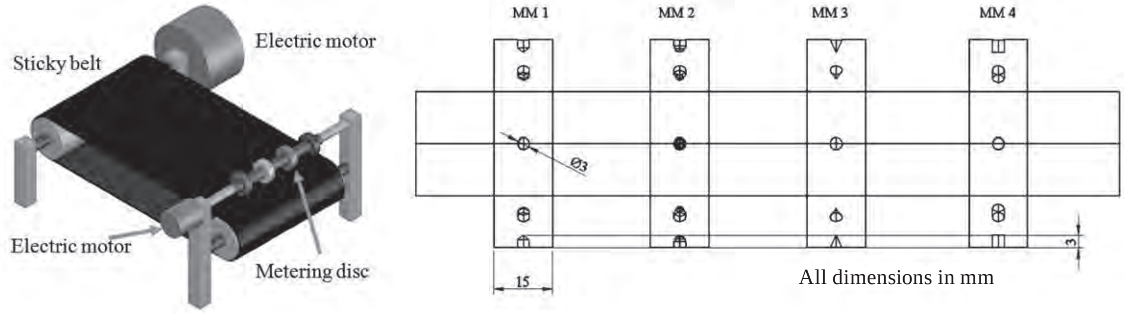
The performance of developed jute seed drill was evaluated at research farm of the institute. The methodology for this testing was adopted from the RNAM test codes and procedures (RNAM, 1995) for related seeding machines such as seed drill. Based on the results obtained from laboratory testing, the performance of the machine was analyzed at field operating speed. Test fields were prepared with one-disk plough for primary tillage and a combination of cultivator and rotary tiller for secondary tillage. After primary tillage field was irrigated by flood irrigation method.

Results and Discussion

Results of Uniformity Test on Different Metering Mechanism

The Uc was used to evaluate the performance of the four different cell shape metering mechanisms in laboratory before final selection of metering mechanism. The average of Uc and CV was measured at speed of 15-50 m min^{-1} for MM1, MM2, MM3 and MM4 (**Fig. 3**). Results of the uniformity tests indicated that speed was important factors for increasing seed discharge uniformity. The coefficient of uniformity increased with increasing auger speed, hence a minimum speed 15 m min^{-1} was selected

Fig. 3 Arrangement of four different metering mechanisms on sticky belt test stand



Maleki et al. (2006). Thus, the faster cell speed provided better seed uniformity distribution compared with lower rotational speed.

Table 1 shows the comparison between the CV and the coefficient of non-uniformity (1-Uc) for all metering devices (MM 1, MM 2, MM 3, and MM 4) used in the study. When focusing on CV, it was observed that the CV range for MM 2 varies between 0.21 and 0.41, representing mostly good and bad performance, respectively. The coefficient of non-uniformity (1-Uc) range varies between 0.22 and 0.29 with SD of 0.02 for MM 2. The results showed that the repeatability of the coefficient of non-uniformity (1-Uc) was substantially higher when compared to the CV in all metering mechanism.The rate of seed discharge uniformity rarely increased for MM 1 while that for MM 2 slightly increased by constant rotational speeds. Thus, for sowing jute seeds with a lower discharge rate (4-6.5 kg/ha), it was found to be better to use MM 2 with lower rotational speed. MM 2, having eight cells yields, had more uniformity in the lower rotational speeds of 15 m min^{-1}. Also the coefficient of uniformity increased as shape of cell tended to be round with slightly higher size than that of jute seed dimensions. MM 2 cells had equal groove diameter, and depth of 3 mm.

Field Performance

Conventional sowing method and developed jute seed drill were evaluated in 100 × 40 m of three plots. Plant populations were measured by counting the number of plants in randomly selected 1 m × 1 m areas after 5 days. Based on these mean values, the plant population per hectare was determined. To determine yield, three randomly selected samples (1 m × 1 m area each) from each plot were harvested. These samples were retted separately, cleaned, weighed, and the average Jute fiber yield was recorded.

Work Capacity and Field Efficiency

The average capacity of the seed drill at the mean traveling speed of 2.1 km/h was varied from 0.23 to 0.3 ha/h (**Table 2**). However, speed significantly affected field capacity. The major time lost was in turning at the headland at tested speed. This varied between 10-13 % of total time. The field efficiency was 69 %, affected by the skills of the driver directly.

Fuel Consumption

The results of the fuel consumption of jute seed drill at field (**Table 2**) was 5.0 l/ha indicated that devel-

Table 1 Coefficient of uniformity (Uc) and coefficient of variation (CV) for four units used in the metering mechanism design

Feed unit	Randomly selection of 10 samples out of 60 samples				Randomly selection of 10 samples out of 60 samples			
	Coefficient of non-uniformity (1-Uc)				Coefficient of variation (CV)			
	Max	Min	Mean	SD	Max	Min	Mean	SD
MM 1	0.42	0.26	0.36	0.057	0.70	0.41	0.58	0.092
MM 2	0.29	0.22	0.29	0.024	0.41	0.21	0.34	0.068
MM 3	0.44	0.34	0.39	0.035	0.62	0.32	0.45	0.104
MM 4	0.38	0.30	0.35	0.024	0.53	0.30	0.40	0.083

Table 2 Results of self propelled jute seed drill and traditional method planting pattern and quality

	Parameters	Sowing with jute seed drill	Conventional method (Broadcasting)
Work capacity	Travelling speed (km/h)	2.1	0.9
	Effective field capacity (ha/h)	0.28	-
	Field efficiency (%)	69	-
	Planting time (%)	84	-
	Time lost (headland, & adjustment)	16	Nil
Fuel consumption	For area tested (3,000 m^2) (l)	1.5	Nil
	Per working hours (l/h)	1.4	Nil
	Per hectare (l/ha)	5.0	Nil
Planting pattern	Row to row spacing (mm)	220	Not maintain
	Plant to plant spacing (mm)	30-60	Not maintain
	Depth of planting (mm)	15-32	Uneven
Planting quality	Mean Emergence Duration (Day)	7.3	7.5
	Germination (%)	67	58
	Saving of labour cost for weeding and thinning (%)	170	-
	Seed rate (kg/ha)	5.6	10.3
	Yield (t/ha)	3.84	2.28

oped drill consumed less fuel. Average fuel consumption was found to be 1.4 l/h.

Planting Pattern

The test results of planting patterns and quality of jute seed drill are shown in **Table 2** and compared with the results obtained using the traditional method. Two factors that affected the pattern of planting were the plant spacing and number of plant in a row. As per the agronomic practices, the sowing depth, row spacing, and plant spacing were set at 15-32 mm, 220 mm, and 16-55 mm, respectively. The machine performed effectively when the narrow opening point was utilized as the seed opener and it was operated at normal planting depth of 15-32 mm.

Planting Quality

The sowing with seed drill and traditional method had almost same emergence and plant population of 530,000 and 775,000 respectively. Mean Emergence duration for seed drill sown crop was 7.2 days. The 67 % germination and plant establishment was found in case of crops sown using the developed seed drill. However, in case of the conventionally grown crop, no uniform germination occurred due to manual broadcasting of seed which is shown in **Fig. 4**. It should also be noted that farmers in the region tend to use 50-80 % more than the recommended seed rates. Higher plant populations could lead to higher thinning cost, moisture stress and reduced crop yield. The crop grown conventionally, growth was adversely affected due to higher plant population. The comparative results are presented in **Table 2**. The higher and non-uniform plant population from the conventional sowing also adversely affected jute yield. The jute yield obtained was 20-28 % higher in the case of the developed seed drill compared to conventionally sown crop under same a normal climatic and condition.

Performance of RLC

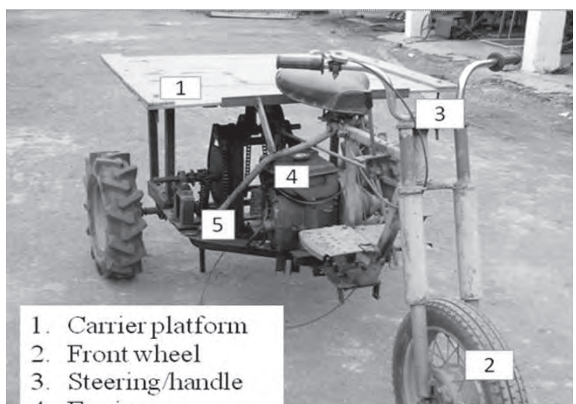
Operator sitting position in seed drill was made in such a way that it can be operated effectively by East Indian villagers, achieving maximum field capacity with efficiency. Between 1.73-8.2 km/h speeds was achieved for transport operation in two different gears. A wooden platform of 1,150 × 1,080 mm was provided for transportation purpose shown in **Fig. 5**. About 800-1,000 kg agricultural inputs and produce could be easily transported on rural road. Ten to twelve rural peoples were also transported for agricultural activity in rural (Kaccha road) and tarmacadam roads. During operation, the operator's could change the gear smoothly without any interruption. A slightly lesser turn would rotate the machine 180º and bring it into position in a narrow road of 2 m and adjacent field with no reverse. Clutch and brake pedals were provided near the left and right fender of the machine respectively. Performance of RLC was also satisfactory at rural road and tarmacadam roads.

Conclusions

On the basis of this research, several conclusions were observed. The best seed discharge uniformity was observed for MM2 which had eight cells at speed between 15-50 m min^{-1}. The CV range for MM2 varied between 0.21 and 0.41 represented mostly good and worst performance, respectively, with SD of 0.068. Narrow shovel type furrow openers width of 52 mm, shear width of 35 mm, boot length of 210 mm rack angle and boot wedge angle of and 90º was selected for wide range of soil conditions in jute

Fig. 4 Self propelled jute seed drill in operation and crop stand grown on the slant

Fig. 5 Rural load carrier with wooden platform of 1,150 × 1,080 mm size



sowing. The average capacity of the seed drill at the mean traveling speed of 2.1 km/h was varied from 0.23 to 0.3 ha h^{-1}. Row to row and plant spacing was found 220 mm and 16-55 mm, respectively. Mean Emergence duration for seed drill sown crop was found 7.2 days. The 67 % germination and plant establishment was found in case of crops sown using the developed seed drill. About 800-1,000 kg agricultural inputs, produce or 10-12 rural peoples were also transported for rural and agricultural activity in rural and tarmacadam roads. The rural road carrier mounted jute drill has functioned reasonably well in field trials.

Acknowledgements

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■■

A Simple Portable Type Kiln for Bamboo Charcoal

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Abstract

The bamboo is one of the fastest growing plant species on earth, which can be used profitably on a sustainable basis. Despite being the second largest bamboo producing country in the world, India has not been able to utilize its bamboo resources in a sustainable manner. Half of the world's population uses biomass fuels for cooking which is rather most easy and least efficient use. Bamboo can easily be converted into good quality charcoal which has several uses. Bamboo charcoal contains several pores and gaps in its structure, making it excellent for adsorption, electromagnetic shielding, and infrared emission. There are different qualities of bamboo charcoal based on parameters such as density, fixed carbon content, ash and volatile matter content, specific surface area, etc. One of the more popular processes used in making bamboo charcoal is while using brick kilns. Construction of brick kiln requires a lot of time, space, money, energy and an enormous amount of biomass material for its conversion into charcoal. Therefore, a simple portable type charcoal kiln was designed, fabricated and evaluated for bamboo culm pieces and found that the conversion efficiency is 33-38 percent for bamboo with a calorific value of 7,742 KCal/kg which is more than oak/pine charcoal available in the market produced in earthen kilns.

Introduction

Bamboo is the fastest-growing plant on Earth; some varieties showing a growth of more than 120 cm in day and unlike trees, all bamboos grow to a full height and girth in a single growing season of 3-4 months. During this first season, the clump of young shoots grows vertically with no or little lateral branching. In the following year, the soft wall of each culm slowly dries and hardens. The culm begins to sprout branches and leaves from each node alternately. During the third year, the culm further hardens and the shoot is now considered a fully mature culm. The growth and maturity for other forest species are slow that it generally takes years to reach maturity before providing wood of commerce. It is a fact that the energy requirements in the Asian countryside are best met by collecting wood from forest and burning in the kitchen primarily for cooking and keeping oneself warm during winter months. However, with increasing urbanization, the forest cover is shrinking fast. It is becoming important to use alternate fast growing plant species with high biomass for this purpose. However, the bamboo because of producing new culms every year, fits very well in this scheme. The mature and dried bamboo can also be converted into charcoal by carbonization at 300 ºC to 600 ºC and only carbon and inorganic ash will be obtained. The vascular structure of the bamboo and the pores created by escaping gases combine to produce a light and porous material. The charcoal thus produced may reduce the load on forest wood as an alternate source of energy. Construction of brick kiln requires a considerable time, space, money, energy and a large quantity of biomass for conversion of charcoal. This much biomass may or may not be available at any given time for the growers, as tiny amount of biomass may result into poor recovery. In addition to this, the mud and brick are porous in nature, so the fire inside kiln can not extinguish totally and it may continue making ash rather than the desired charcoal. It is one of the major reasons for over burning and poor recovery. There are many types of systems developed in the past for converting plant biomass into valuable charcoal more so using bamboo as raw material but these suffer from various drawbacks. Generally, a number of charcoal kilns that were developed were expensive, less efficient or user unfriendly. So, a simple portable type charcoal kiln was designed, fabricated and evaluated for bamboo, sticks and culm pieces.

A large number of charcoal kilns have been developed in past in different countries for conversion of biomasses in to charcoal. Some of the important details are given in the following pages:

Matsuoka (1988) developed a water sealed charcoal kiln which was provided with freely openable at upper and lower lids and sealing with water. Maurice (1988) created a transportable large capacity rectangular bin with detachable cover. The floor of bin was in the form of double layered sheet metal, divided in to a series of lengthwise air channels with vertical spacer with apertures, hinge shutters controlling air in the kiln. Hideo (1994) developed a conical charcoal kiln, equipped with traversing rail for opening and closing of kiln unit and an electrical hoist for the movement of whole assembly. It had a penta layered platform viz. concrete, clay, black soil; sand and concrete layer with central core being made up of iron for making complete air tightness at the bottom but this would run only where electricity was available. Takeshi (2001) invented a charcoal kiln which was equipped with blower and inverter for carbonization and control of air flow rate of blower respectively. Darshan *et al.* (2001) studied charcoal conversion of coconut shells under four different types of charcoal kilns and found 30.2, 28.5, 28.2 and 13.83 % recovery under drum kiln, lined pit kiln, unlined pit kiln and heap burning respectively. Earlier, Zahid (1996) had found 19.1 % recovery using coconut shells in his brand of kiln. Solov'ev *et al.* (2002) developed a charcoal kiln having detachable housing, which had provision for changing their spatial position by circular displacement inside the kiln through rotating wheels driven by an electric drive. Yasuhiro (2002) developed twin containers charcoal kiln which was placed on an appropriate external a heat source for conversion of biomass. Similarly Mametora (2003) invented a twin vessel horizontal cylindrical charcoal kiln with circulating burner flame through a gap between the inner wall of oven body and the inner vessel for baking the charcoal material in the vessel. Another charcoal kiln with fire grate and exhaust system assembly to control the inside temperature of the kiln was developed by Zuito (2003). A little later, Bakaev *et al.* (2004) demonstrated an automatic mobile paraboloid charcoal kiln having an outer heat insulating housing and inner casing and equipped with a sealing door. Another type of cylindrical charcoal kiln, openable from the top and bottom and closed by a lid was patented by Yukio (2005) where the hot flame generated from the fuel was introduced into a space between combustion chamber open end, which was exposed in a ring shape between the lower edge circumference of drum shaped container and the top opening circumference of combustion chamber. Jun Qian *et al.* (2005) invented a long type charcoal kiln which had three portions viz. 1) combustion chamber 2) charring chamber and iii) chimney. The front side of combustion chamber was connected with air and fuel inlets and rear side with an arched charring chamber having biomass material inlet and outlet and a chimney at the rear end for exertion of gases through a control valve. Toshiaki (2006) developed a cylindrical charcoal kiln with openings at the bottom and the side and also it has been provided with an air intake duct at bottom of inner kiln having an air intake pipe on one end which was projected outside the kiln but because of many openings, it was proved to be the user unfriendly. In the same year Masatoshi (2006) developed a double walled dome shape structure of stainless steel at front and a brick structure at rear end with front and rear wall surfaces provided with detachable lids. The unit had firing and loading of biomass at front and detachable exhaust pipe at the rear side for baking of biomass. Tosuke (2006) developed a cylindrical batch type charcoal kiln where raw material was loaded in a sliding chamber and fire hole was provided in the front side and a smoke-emitting portion at the rear side wall. And more recently Futoshi (2007) developed a multi chambered charcoal kiln, which was fired by external burners and was used for conversion of bamboo and other biomass into charcoal.

Materials and Method

However all the kilns developed earlier on, suffer from many defects such as being expensive, unfriendly in use, too complicated, therefore, requiring skilled manpower or being stationary or even too large and being run on electric power and thus limiting their usage. Therefore, an alternative mobile, comparatively inexpensive, easy to operate kiln was designed by using the diesel drums with good efficiency of conversion of biomass.

Conventionally charcoal is prepared in brick kilns with dome shaped body. Loading of this type of kiln is done from top and sides. Square openings are provided on the body of charcoal kiln in diamond shape. The front openings are closed by brick and soil mortar and top opening by a heavy steel plate with soil after firing the kiln. The openings on the main body could be closed, one by one from the top when the fire reaches at that point. The body of the conventional charcoal kiln is required to be sealed by smearing the whole body with clay soil mixed with molasses. Once the fire is at its prime and spreads allround within the kiln, all the openings are sealed for putting off the fire and subsequent cooling of kiln.

The portable charcoal kiln (**Figs. 1** and **2**) mainly consists of main body of portable kiln, chamber for water seal for restriction of air movement, air vents for regulation of air movement in the main body, drainage system to the water sealing unit, MS handles on kiln body for moving the portable charcoal kiln, chimney for exhaust system, control valve of exhaust unit, vacuum gauge for detecting burning of charcoal, lid for covering the main body, MS handles of lid for easy opening and closing of the unit, transport wheels for movement of portable charcoal unit, heat sealing material, MS rode grill for easy peripheral circulation of air and end caps for regulation of air. A heat sealing material (mixture of clay and molasses) was thoroughly prepared and a thin layered coating was made in side the wall, bottom and covering lid as to prevent direct exposure of fire whose temperature ranged from 300-600 ºC. In case of uncoated portable kiln, life may be reduced. The top opening on the body of portable kiln was acting as an exhaust port and lower acted as an inlet valve for aeration to biomass. The collapsible grill was assembled in the main body and bamboo biomass was loaded vertically in layer and firing was made. Once the fire catches to bamboo biomass at first layer, the successive layers were assembled in the same fashion. Once the fire reaches the top of the portable kiln, it was covered by a lid with exhaust port kept in open position and water was filled in water seal. The exhaust ports were kept open till the whitish smoke was driven out from top and closed one after another from top to bottom, once fire was located at that point. Those ports in lower zone were closed lastly. The vacuum gauge would indicate a negative pressure at the time of the completion of burning process. After due cooling, the kiln was opened to recover the charcoal which is ready for use.

Result and Discussion

The conventional charcoal kiln prepared by the mud and brick are porous in nature and the fire in side kiln can not extinguish totally and it goes on making ash from the charcoal. In addition to this, there is a poor aeration near the body of charcoal kiln and biomass which results into un-burnt /partially burning of biomass. The quantity of partial burnt biomass was 2-4 % (**Table 1**). Moreover, the temperature of the burning biomass at the centre of the kiln was very high and porous nature of kiln material results into over burning biomass and poor recovery of charcoal. Besides, four men are required through out the burning of biomass whereas a single man can handle the portable charcoal kiln. The conversion efficiency of portable and conventional charcoal kiln was 33-38 and 30-33 percent with time required was 1.5-2.0 and 24-27 hours respectively. We also made an attempt to make an analysis of the moisture content and calorific value of the commonly available pine wood charcoal and the bamboo charcoal manufactured in the present kiln developed by us through the services of our sister lab i.e. CSIR- IMMT at Bhubaneswar, Orissa (India) and as revealed in **Table 2**.

Conclusions

A simple portable charcoal kiln for bamboo was developed for complete aeration of biomass for easy burning provided with a control valve for regulation of air and removal of gases and complete re-

Fig. 1 Portable type charcoal furnace

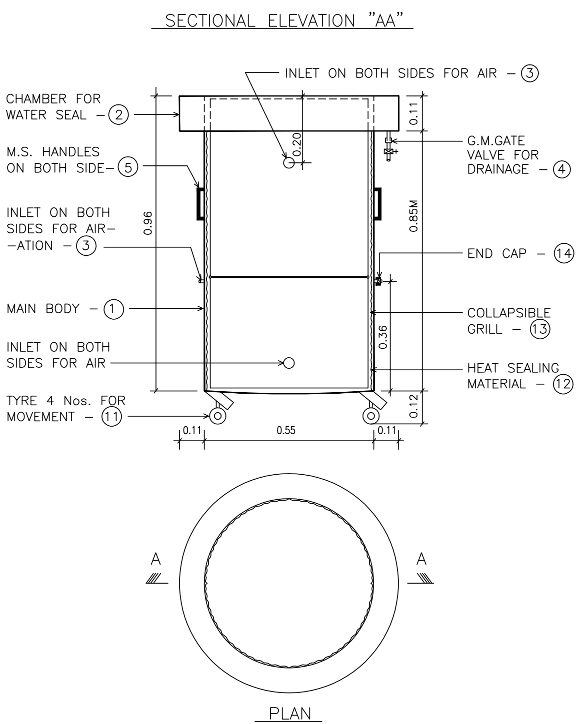

Fig. 2 M.S. Lid for covering of charcoal furnace

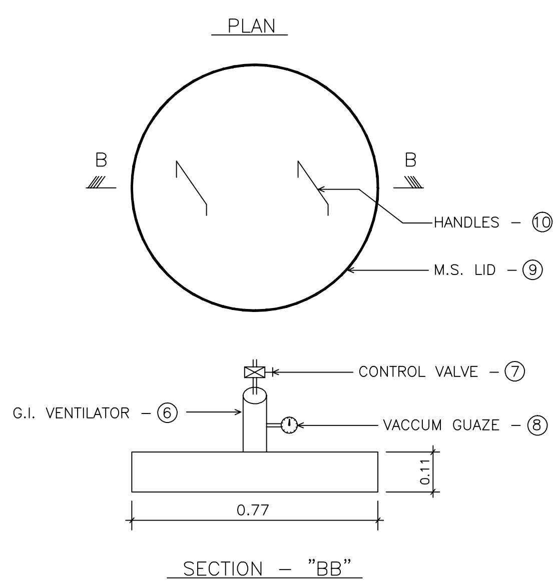

Table 1 A comparative study of conventional and portable charcoal kiln

Particulars	Conventional kiln			Portable type charcoal kiln			Efficiency of conversion	
	Workers needed man day	Weight of biomass loaded, Kg	Time required, hr	Weight of biomass loaded, Kg	Workers needed	Time required, hr	Conventional	Portable type
Bamboo	4	1,500	24-27	50	1	1.5-2.0	30-33	33-38

Table 2 Analysis of bamboo and wood charcoal (by: CSIR-IMMT, Bhubaneswar)

Type of charcoal	Moisture content (%) Dry Basis	Calorific value (Kcal/Kg.)	Calorific value at 0 % moisture (Kcal/Kg.)
Wood charcoal	7.33	7,075	7,634
Bamboo charcoal	7.65	7,150	7,742

striction of air movement when it was not desirable. This resulted into good recovery of the charcoal with almost same calorific value 7,742 K Cal/kg at zero % moisture (tested by CSIR-IMMT Bhubaneswar). The charcoal thus produced may reduce the load on forest wood due to urbanization by providing an alternate source of energy. Bamboo charcoal contains several pores and gaps in its structure, thus making it excellent for adsorption, electromagnetic shielding, infrared emitting and further conversion into high quality activated carbon for industrial applications.

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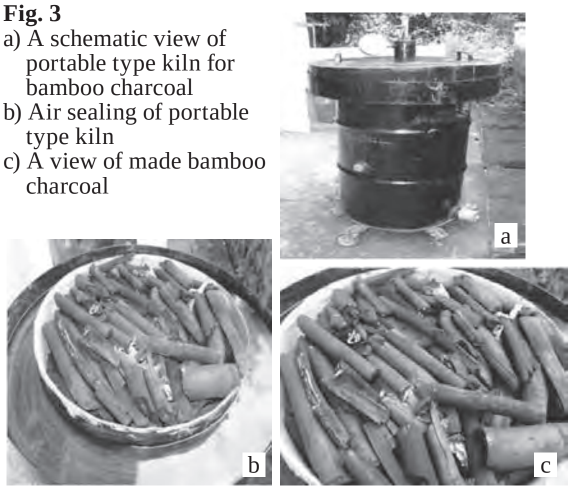

Fig. 3
a) A schematic view of portable type kiln for bamboo charcoal
b) Air sealing of portable type kiln
c) A view of made bamboo charcoal

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Metering Mechanism and Performance of a Torsional Vibration Meter


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Abstract

Torsional vibration meter has good adaptability for rice seed with characteristics of no damage, stable metering, and easy control. In order to obtain the optimum parameters of a torsional vibration meter for rice seed metering, the metering mechanism and metering performance were theoretically studied and experimentally validated in this study. Seed kernels in the metering plate, subjected to forces of gravity, friction, inertia, etc., moved uniformly along the seed rail, and the amplitude of vibration of the metering plate had much influence on the movement of the seed kernels. The optimum value of the amplitude was 0.173 mm, and the values of helix angle of the seed rail and angle of vibration were 2.5º and 23º, respectively. The metering rate data from experiment agreed well with that from calculation based on metering mechanism analysis, with difference less than 5% while the value of amplitude of vibration was 0.173 mm.

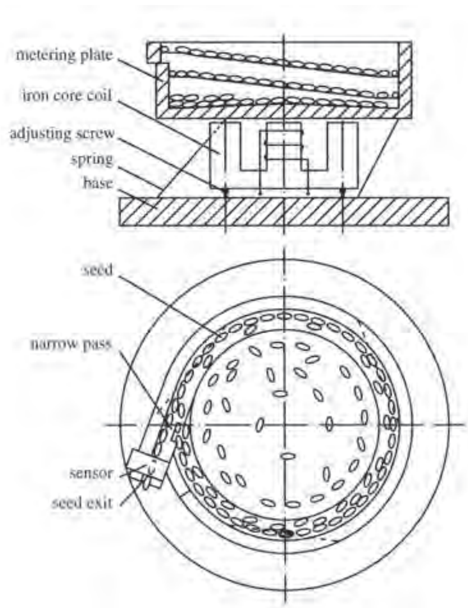
Introduction

Rice is one of the main crops in the world, on which 50 % of all population relies as staple food. In China, rice production amounted to 202.5 million tons with planting area 30.4 million hm^2 in 2011. And the mechanization rice planting level of 20 % was quite low compared to its overall mechanization level of 58 % in 2010 (Zhu, 2012). The main obstacles that prevent the mechanization level of rice planting are the irregular shape of rice seed and the traditional agronomic technology of seed germination by soaking acceleration before metering (He, 2003). Different metering devices were presented for the rice seed, such as fluted wheel one, vacuum one, and vibration one, of which the vacuum metering device was mostly studied (Wang, 2009; Yang, 2010; Wang, 2010). But the seed is easy to be damaged for the fluted wheel meter; the nozzles are easy to be clogged for the vacuum meter; and it is difficult to control the metering process of the linear vibration meter. In this paper, a torsional vibration meter was presented, and the metering mechanism and its metering performance of rice seed were theoretically studied and experimentally validated.

Meter Structure and the Metering Process

The structure of the torsional vibration meter is shown in **Fig. 1**. The metering plate is held by 3 plate-springs which are evenly distributed along the circumference. An iron core coil is stalled under the metering plate with an adjustable

Fig. 1 Meter structure and its work principle



clearance from the bottom of the metering plate. A spiral seed rail is manufactured around the inner wall of the metering plate, and a narrow pass is set near the seed exit of the seed rail.

While metering, a unidirectional pulse voltage is supplied to the iron core coil, which produces an electromotive force to the metering plate. The metering plate torsionally vibrates under the action of the electromotive force and the springs. Seed kernels in the metering plate, subjected to forces of gravity, friction, inertia, etc., move uniformly along the seed rail, and some are pushed down the rail. Finally, the seed kernels creep through the narrow pass one by one and are sensed by a photoelectric sensor. The metering process is controlled by switching on/off states of the voltage input.

Metering Mechanism

Forces Acting on the Seed Kernel

For the purpose of force and movement analysis of the seed kernel on the seed rail, expanded the seed rail along the circumference and set the coordinate system, as shown in **Figs. 2a** and **2b**, where x is tangent to the spiral seed rail with a helix angle α and y is perpendicular to the rail.

Metering plate periodically vibrates along vibration direction s, and δ is the angle between s and x. While metering, forces acting on a seed kernel are as follows: gravity mg; supporting force N_s; friction force F_s; inertial force ma; m is the mass of the seed kernel while g and a are gravitational acceleration and vibration acceleration, respectively.

To retain the seed kernels on the spiral rail well, an inclination angle α_1 is set on the rail, as shown in **Fig. 2c**. Then, there are other forces acting on the seed kernel: supporting forces N_w and N_i by the wall and the inclined rail surface, respectively; friction force F_i; inertial force $m\omega_1^2r$ away from the axis of the metering plate. The r is the radius of the seed position away from the axis of the metering plate; ω_1 is angular velocity of the seed kernel, and $\omega_1 = V/r$, where, V is velocity of the seed kernel. N_i is away from N_s with a direction change of angle α_1. Then, the co-acting forces of N_i and $m\omega_1^2r$ with a resultant force $N_i\sin\alpha_1 + m\omega_1^2r$, with direction away from the axis of the metering plate, keeps the seed kernels on the rail well.

Moves of Seed Kernel on the Seed Rail

The displacement of the metering plate along vibration direction can be expressed as

$S = A \sin \omega t$ .... (1)

where S is displacement, mm. A is amplitude of vibration along the vibration direction, mm. ω is angular frequency, rad/s, and $\omega = 2\pi f$ (f is frequency of the vibration, Hz) and t is time, s.

The displacement components of S along x and y are expressed as

$S_x = A \sin \omega t \cos \delta$ ....(2)

$S_y = A \sin \omega t \sin \delta$ ....(3)

By applying derivation and secondary derivation to **Eqn. 2** and **Eqn. 3,** the velocity and acceleration components of the metering plate along x and y can be obtained.

Considering relative move of the seed kennel to the seed rail, with relative displacement Δx and Δy, relative velocity $\Delta\dot{x}$ and $\Delta\dot{y}$, and relative acceleration $\Delta\ddot{x}$ and $\Delta\ddot{y}$, there are

$F_x = m(a_x + \Delta\ddot{x}) - mg \sin \alpha - F_s$.
....(4)

$F_y = N_s + m(a_y + \Delta\ddot{y}) - mg \cos \alpha$
....(5)

where F_x and F_y are the resultant forces along x and y, respectively, N. a_x and a_y are the acceleration components of the metering plate along x and y, respectively, m/s^2.

To obtain good metering performance, sliding movement is better than throwing movement for the seed kernel on the seed rail. For the sliding movement, there are $N_s \geq 0$ and $\Delta\ddot{y} \neq 0$; and for the throwing movement, there are $N_s = 0$ and $\Delta\ddot{y} \neq 0$. Then, the friction force acting on the seed kernel while sliding can be expressed as

$F_s = \pm f_s N_s$ ....(6)

where f_s is the maximum friction coefficient, and $f_s = \tan \mu_s$. μ_s is the static friction angle. "+" correspondences to forward movement (sliding up), and "–" correspondences to backward movement (sliding down).

While the seed kernel starts to slide, there are $\Delta\ddot{x} = 0$ and $F_x = 0$ for **Eqn. 4**, then

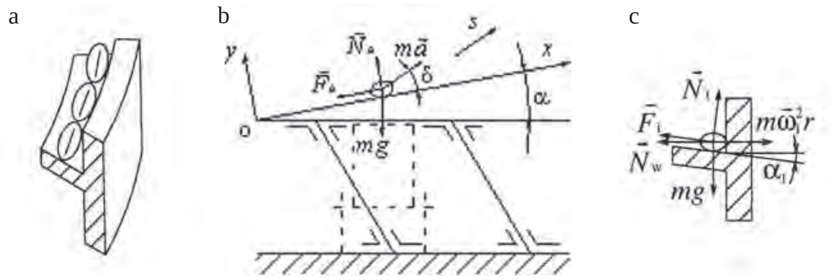
$\varnothing_{f0} = \arcsin (1/D_f)$ ....(7)

$\varnothing_{b0} = \arcsin (1/D_b)$ ....(8)

where $\varnothing_{f0}$ and $\varnothing_{b0}$ are the start angles of forward movement and backward movement, respectively. D_f and D_b are the indices for forward and backward movement, respectively, and $D_f = K \cos (\mu_s - \delta)/ \sin (\mu_s - \alpha)$, $D_b = K \cos (\mu_s + \delta)/ \sin (\mu_s + \alpha)$ (where is vibration strength, and $K = A\omega^2/g$ (Zhang, 1996).

While the seed kernel ends the slide, there are $\Delta\dot{x} = 0$ and $F_x = 0$

Fig. 2 Forces acting on the seed kernel



a. seeds on the spiral rail, b. forces on the linearly expanded seed rail, c. forces on the inclined rail for **Eqn. 4**, then the end angles for forward and backward movement can be calculated. Thus, the mean forward slide velocity can be obtained by dividing relative displace Δx, resulting from integral of relative velocity $\Delta\dot{x}$, by time period of forward slide, and the mean backward slide velocity can be obtained by applying the same method. Then

$V_f = (A\omega P_f / 2\pi) \cos\delta \, (1 + \tan \mu_d \tan \delta)$ ......(9)

$V_b = (A\omega P_b / 2\pi) \cos\delta \, (1 - \tan \mu_d \tan \delta)$ ......(10)

where V_f and V_b are the mean forward slide velocity and the mean backward slide velocity, respectively, m/s. μ_d is the dynamic friction angle of seed kernel on the seed rail. P_f and P_b are the velocity coefficients of forward slide and backward slide, respectively, and they can be determined through curve lookup after knowing the corresponding start angle and end angle of the slide (Wen, 1982).

Then, metering rate of the seed kernels can be expressed as

$Q = 60 \, (V_f + V_b)/l$ ......(11)

where Q is the metering rate, kernels/min.; l is the mean length of the rice seed kernels, mm (Yang, 2000).

Movement of other Seed Kernels

Four factors affect the movement of the seed kernels that are not on the seed rail.

Firstly, there is no helix angle for the seed kernels on the inner bottom surface of the metering plate. By setting $\alpha = 0$ and x being horizontal in **Fig. 2b**, the resultant force F_x in **Eqn. 4** becomes

$F_x = m \, (a_x + \Delta\ddot{x}) - F_s$ ......(12)

The force F_x lets the seed kernels have a counter-clockwise move of revolution in the metering plate.

Secondly, there is no radial confinement for the seed kernels until they come in contact with the wall of the metering plate. By analogy to the forces described in **Fig. 2c**, the co-act forces Ni and inertial force $m\omega_2^2 r_i$ let the seed kernels move away from the axis of metering plate until they come into contact with the plate wall. ω_2 is angular velocity of the seed kernels on the seed rail. r_i is the radius of the seed position away from the axis of the metering plate, and the value of r_i changes with the move of the seed kernels.

Thirdly, there is no open exit for the seed kernels, and the seed kernels can only climb on the seed rail or crowd forward by the forces mentioned above.

Fourthly, the seed kernels are in the state of thick layers. During metering and vibration, there are collisions and friction between seed kernels, which greatly affects the moves of the seed kernels. With the increase of numbers of the layers, higher vibration strength K is needed to keep the up-layer seed kernels loose (Yang, 2010; Zhang, 2008).

Performance Experiment and Analysis

Material and Method

Based on metering mechanism and some pre-experiments, the parameters of the meter were determined as follows: helix angle of the spiral seed rail $\alpha = 2.5^o$; angle of vibration $\delta = 23^o$; frequency of vibration; $f = 50$ Hz; total stiffness of the springs 9.8×10^4 N/m. The material of the metering plate was 45 steel and the surface of seed rail was dealt with paint spraying.

The rice seed for experiment was IIyou 838 with moisture content of 15 % db, and it was coated with seed coating agent of brand Xinong. The 1000-grain weight of the rice seed was 24.5 g, and the mean length of the seed was 7.81 mm. The static friction angle of the rice with seed rail $\mu_s = 34.25^o$, and the dynamic friction angle of the rice seed with seed rail $\mu_d = 30.87^o$ (Yang, 2000).

The metering rate by changing the amplitude of vibration was recorded in the experiment, and the calculated metering rate was obtained from **Eqn. 11**. The change in the amplitude of vibration was realized by adjusting the input voltage of the iron core coil. For calculation, the start angles $\o_{f0}$ and $\o_{b0}$ of forward and backward movement of the seed kernel were assumed to equal to the actual start angles of forward and backward movement to obtain the velocity coefficients p_f and p_b of forward slide and backward slide.

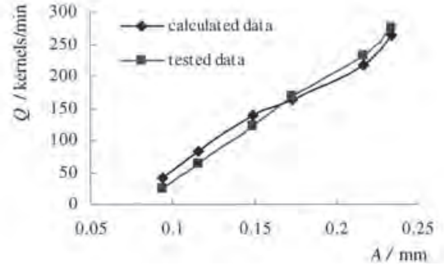
Results and Discussion

The metering results from experiment and calculation and the metering observation are listed in **Table 1**. The relationship between the metering rate and amplitude of the vibration and the comparison of the

Table 1 Metering results and observation

Amplitude A / mm	Calculated Q / kernels·min^{-1}	Tested Q / kernels·min^{-1}	Metering observation
0.094	42	24	Start metering
0.116	82	63	Slow
0.150	138	123	Slightly slow
0.173	163	168	Good
0.217	218	231	Speedy
0.235	264	276	Start throwing

Fig. 3 Relationship between metering rate and amplitude of vibration



experiment data and calculated data are shown in **Fig. 3**.

Metering rate nearly increases linearly with the increase of amplitude of vibration. There is a dead zone for the amplitude of vibration because of gravity and static friction acting on the seed kernels. When the amplitude of vibration reaches 0.094 mm, metering process starts with a quite slow metering rate; when the amplitude of vibration reaches 0.173 mm, good metering performance is obtained; and when the amplitude approaches to 0.235 mm, seed throwing starts and the throwing has a bad effect on the metering process control. Thus the optimum amplitude of vibration of the meter was 0.173 mm.

The metering rate data from experiment coincide well with that from calculation, with difference of the data less than 5 % while amplitude of vibration is 0.173 mm, which shows that the metering mechanism presented is suitable for the torsional vibration meter studied.

When a type of rice seed is changed, the torsional vibration meter can also obtain good metering performance. But on such circumstances, the optimum amplitude of vibration of the meter should somewhat be adjusted, because there are different coefficient values of static friction and dynamic friction between rice seed of different type and seed rail of the meter.

Conclusions

The metering mechanism and metering performance of a torsional vibration meter were theoretically studied and experimentally validated in this study. The following conclusions were obtained from the study:

1. The torsional vibration meter has good adaptability for rice seed metering with characteristics of no damage, stable metering and easy control.
2. Seed kernels in the metering plate, subjected to forces of gravity, friction, inertia, etc., move uniformly along the seed rail. Amplitude of vibration of the metering plate has much influence on the movement of the seed kernels, and the optimum value of the amplitude is 0.173 mm.
3. The metering rate data from experiment coincide well with that from calculation based on metering mechanism analysis, with difference less than 5% while the value of amplitude of vibration was 0.173 mm.

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Design and Fabrication of Evaporative Cooling Transportation System

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Abstract

Fruits and vegetables are presently packed and transported in jute bags and basket in open vehicle without any cooling arrangement. This results in both loss of quality and quantity and even shelf life decreases. Evaporative cooling system is appropriate for reducing the temperature of produce during transportation so as to minimize loss and to enhance shelf-life. Evaporative cooling system suitable to fit on trucks has been developed and evaluated. The developed system helps to minimize the PLW (Physiological Loss in Weight), preserve the freshness and increases the shelf-life of the agriculture produce as compared to prevailing traditional transport system. Percent saving in PLW was observed higher (above 50 %) in fenugreek, shelf-life of cucumber & leafy vegetable increased 200 & 100 percent respectively. The maximum saving in PLW was 79.98 % in fenugreek while least 7.03 % was observed in capsicum.

Introduction

The present production of fruits and vegetables in India is around 209.72 million tonnes per year (Amrat Lal *et al.,* 2011). These commodities are highly perishable due to their high moisture content and soft texture and therefore, undergo high post harvest losses. Storage at ambient condition results in high weight loss and rapid deterioration in chemical composition (Awole *et al.,* 2011). About 30 % of the fruits and vegetables grown in India get wasted annually due to gaps in the cold chain such as poor infrastructure, insufficient cold storage capacity, unavailability of cold storages in close proximity of farms, poor transportation infrastructure, etc (Maheshwar and Chanakwa, 2012). High perishability, lack of storage facilities, mechanical injuries due to improper handling, packaging, lack of cooling arrangement during transportation etc. are the major causes for post-harvest losses in fruits & vegetables. As a result, at times there is acute shortage of these commodities which leads to price increase and ultimately inflation rises.

In most part of India, hot and dry weather prevails for a significant part of the year, the high temperature is responsible for the rapid deterioration of perishable produce. Due to lack of the cooling arrangement during transportation considerable amount of the perishable agricultural produce is lost after harvest. Pal *et al.* (2002) reported losses up to 29.5, 10 and 19.4 % in onion, cabbage & water melon respectively. Goyal *et al*. (2005) conducted a study on road transport of tomato and reported a loss of 6.91 %. The maintenance of low temperature during transportation is a great problem. Transportation of fruits and vegetables through mechanical refrigeration is not economical. Fast transport of fruit and vegetables with minimum damage during shipment is very important in successful marketing of perishables. In India, road transport is preferred for shipment of fresh fruits and vegetables, simply because of the faster movement of perishable commodities and advantages of door-to door service.

The present system of transporting fruit and vegetables by road trucks is highly defective and needs thorough improvement. The road trucks should have a special system of ventilation and arrangement to reduce temperature and maintain proper relative humidity. This can successfully be done without using high-cost mechanical refrigeration, simply by adopting the technique of evaporative cooling with a slight modification in the existing road trucks. Efficient transportation system can go a long way not only in reducing the post harvest loss of horticultural produce but also in stabilizing the price fluctuation of the same commodity available in different corners of the country.

There are no facilities to maintain

the condition of the produce while in transit and proper ventilation (Eric & Bani, 1998). The objective of this study was to develop a suitable transport system for cooling and safe transportation of perishable commodities.

Material and Methods

A laboratory model evaporative cooling (EC) transport system was developed (Vala & Joshi, 2006). The wet pad type, pad thickness, water requirement, air velocity etc. were standardized using a simulation model in the laboratory with respect to the ambient conditions and requirements of green vegetables. The optimized parameters were used to design and develop the scaled-up version of the EC system to be used for road transport of fresh fruits and vegetables.

The evaporative cooling system has been designed for small commercial vehicle as a working model. The TATA ACE mini truck is one of the most popular vehicles used for transporting fresh fruits and vegetables from the farm to the markets. Goyal *et al.* (2005) conducted the road transport (400 km) of tomatoes in three packaging medium using TATA-407 vehicle. The various components of evaporative cooling system namely; 1) the cooling component in which pad is fitted in a holder and water is sprayed over it when vehicle moves. This makes the air cooled; 2) the air distribution component consisting of air duct carries the cool-wet air and evenly distributes in truck stack body; 3) storage space available at the back of the truck for storage of fruits and vegetables. Accordingly, the various components of the evaporative cooling transportation system were designed and fabricated. For this removable body frame structure was made and was covered appropriately to make it a closed space. The component wise details are given here under.

Body Frame Structure

For designing the cooling system and storage arrangement dimensions of the actual available space at the back of the truck has been considered.

The body frame structure was designed to fit the vehicle size. The structure was fabricated using mild steel square bar. The overall dimensions of structure were 2175 × 1450 × 1750 mm. It was fitted using nuts and bolts. This helps in quick fitting and equally quick removal as needed.

Pad Holder

To get the maximum cooling inside the EC structure, the length of the pad holder was considered as the maximum width of the truck top available. Actual height available above driver's cabin on mini truck was found to be equal to one-forth of the total loading height. Therefore, the height of pad holder was considered as one forth of the designed EC structure height. The width of the pad holder was kept as 100 mm equal to the thicknesses of pad material required. Hence, the dimensions of the developed pad holder were 1200 × 100 × 300 mm. The pad holder was fabricated using mils steel angle and wire mesh.

Air Duct

To distribute the cool air inside the truck storage body, width of the duct was kept equal to length of the pad holder. The height of duct was kept up to bottom of the truck body. Circular holes of different sizes were made on back side of the air duct for even distribution of air. To handle the quantity of air coming from wet pad, the size of air duct was kept equal to the thickness of pad holder/pad. Thus the overall dimensions of the air duct were 1200 × 100 × 1500 mm. The duct was fabricated using mild steel sheet.

Water Distribution System

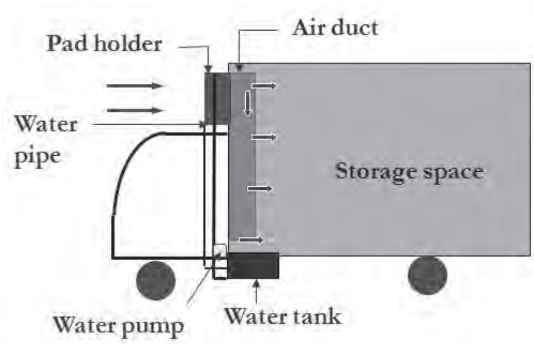
To insure complete wetting of the pad area, as thumb rule, water must be delivered at the top of a 100 mm thick celdek pad at a rate of 2.7 Lpm per linear foot of pad. Accordingly water requirement was calculated to be 2.7 Lpm i.e. 3 Lpm. For continuous supply of water, a tank of 60 litre capacity was fitted at one side of the EC system.

For circulation of water, a vehicle battery operated small pump of 3 Lpm was fitted over the water tank. Piping system was made to spray water over cooling pad and was collected back in the tank.

All the components as described above were fitted in the vehicle (**Fig. 1**). The whole storage space was covered from all sides and top, made completely air tight with tarpaulin sheet. The line diagram of

Fig. 1 Components were fitted in the vehicle

Fig. 2 vehicle fitted with the EC system



the vehicle fitted with the EC system is given in the **Fig. 2**. The pad holder was fitted over truck cabin facing front side of the system. Before starting the experiment, water distribution system was run to get steady-state condition. The necessary arrangements of sensors/data logger for recording observations inside and outside of the structure were made. The developed system was tested with load at an average speed of 50 km/h over a distance of about 100 km one way.

Testing with no-load Condition

The EC transport system was run without any load to check the variation of temperature and relative humidity inside the modified structure. Three such runs were conducted and the average data wer reported.

Testing with Load Condition

Fresh selected vegetables were procured from the local market (tomato, green chilly, ladies finger, cluster bean, capsicum, cucumber, spinach, coriander, tandaljo and fenugreek) and were immediately sorted and cleaned. Vegetables were weighed and kept in plastic crates. Two set of crates were prepared with fixed sample size (2 kg to 3.5kg) for each vegetable. One set was kept above the structure and covered by green net as the traditional transportation as control sample, while another set of each vegetable was stacked inside the storage structure and made fully air tight. Immediately after the run, transported vegetables were unloaded and weighed for PLW (Physiological Loss in Weight). Visual quality analysis was done by seven expert panelists with following indices and was immediately kept inside evaporative cooled storage structure for determination of shelf-life.

Rating Indices
Leafy Vegetables
Fresh & tender
Fairly tender
Wilted
Wilted & dry
Fruits & Other Vegetables
Hard
Slightly hard
Firm
Fairly firm
Pulpy & soft

(Dadhich *et al.*: 2008)

Results and Discussion

No-Load Testing

The vehicle complete with evaporative cooling system was run on road for about four hours. The variation in temperature and relative humidity obtained inside the EC chamber vis-à-vis the ambient condition is shown in **Figs. 3** and **4**.

Fig. 3 Variation in temperatures in EC vehicle-without load

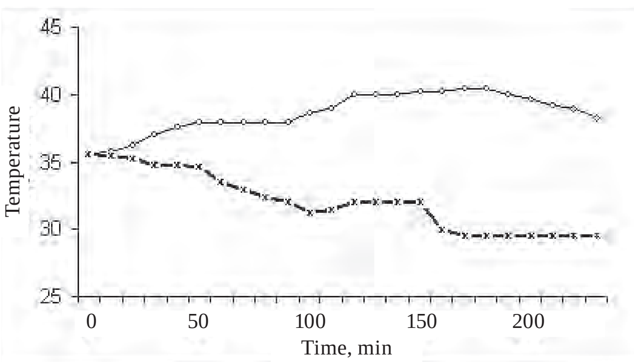


Fig. 4 Variation in relative humidity in EC vehicle- without load

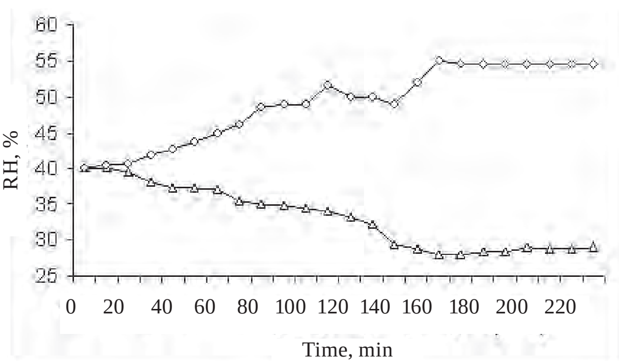


Fig. 5 Variation in temperatures in EC vehicle -with load

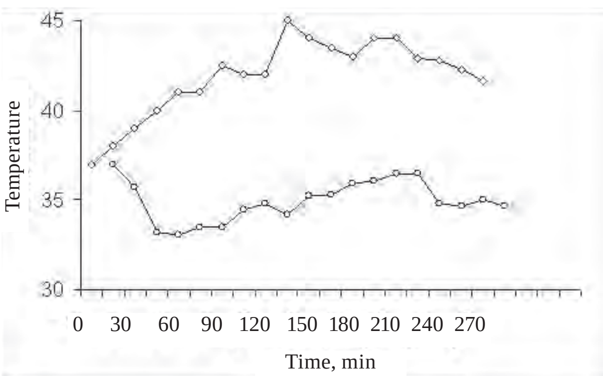
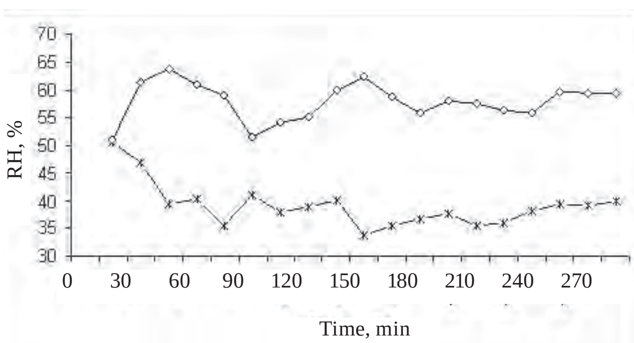


Fig. 6 Variation in relative humidity in EC vehicle-with load



From the **Fig. 3**, it is observed that the temperature inside the vehicle chamber went on reducing as the time of run increased. At the start of the run, temperature drop was lower, which further decreased. The maximum temperature drop obtained was 11.0 ºC. Similarly, the relative humidity inside the chamber also went on increasing as the vehicle progressed. From an initial value of about 40 %, the relative humidity increased to about 55 % (**Fig. 6**).

Table 1 Visual quality of vegetables immediately after transportation

Vegetables transported	Acceptance rating		Vegetables transported	Acceptance rating	
	Traditional Transport	Evaporative Cooling Transport		Traditional Transport	Evaporative Cooling Transport
Spinach	2	3	Green Chilly	3	3
	1	3		3	4
Coriander	1	3	Cluster bean	3	3
	1	3		2	4
Tandaljo	1	3	Okra	2	3
	1	3		3	4
Fenugreek	1	3	Capsicum	3	4
	1	3		3	4
Tomato	2	4	Cucumber	2	3
	3	4		3	4

Table 2 Physiological Loss in Weight of vegetables immediately after transportation

Name of vegetable	Physiological Loss in Weight (PLW)		Difference in weight loss over traditional transport (%)	% saving in PLW
	Traditional transportation (%)	Evaporative cooling transportation (%)		
Capsicum	5.69	5.29	0.40	7.03
Chilly	4.58	3.19	1.39	30.35
Tomato	1.09	0.35	0.74	67.89
Okra	3.32	1.47	1.85	55.72
Spinach	10.35	7.40	2.95	28.50
Coriander	10.19	3.95	6.24	61.24
Tandaljo	11.11	6.18	4.93	44.37
Clusterbean	4.35	3.42	0.93	21.38
Cucumber	4.05	2.38	1.67	41.23
Fenugreek	9.09	1.82	7.27	79.98

Table 3 Shelf-life of vegetables in evaporative cooling storage structure immediately after Transportation

Name of vegetable	Shelf-life		
	Control (traditional) transport (days)	Evaporative cooling transport (days)	Gain over traditional transport (%)
Capsicum	9	13	44.44
Chilly	6	10	66.67
Tomato	18	21	16.67
Okra	5	9	80.00
Palak	1	2	100.00
Coriander	1	2	100.00
Tandalajo	1	2	100.00
Clusterbean	6	11	83.33
Cucumber	1	3	200.00

With-Load Testing

The vehicle was loaded with plastic crates having different vegetables and the system was tested on road. **Figs. 5** and **6** show the variation in temperature and relative humidity in the EC chamber when tested with load. The data reveal that the temperature inside the chamber gradually reduced and the relative humidity gradually increased. On an average, there was temperature drop of about 7-8 ºC with 9.8 ºC as the maximum drop in temperature. The temperature drop was stabilized after about one hour of the run. However, there was little variation in the temperature drop during the test run (**Fig. 5**).

There was increase in the relative humidity inside the chamber as the truck moved further. Again the relative humidity was stabilized to about 55-60 % after about one hour of the run (**Fig. 6**).

Quality of Product after Transportation

As explained earlier, the visual inspection of the vegetables with respect to different quality attributes was done immediately after transportation. The sensory score was higher for all the vegetables which were kept in the evaporative cooled transport as compared to the control transport (**Table 1**). The leafy vegetables looked fresh at the end of the transportation as compared to those which were transported without cooling.

Physiological Loss in Weight (Plw)

Vegetables were weighed before and immediately after the transportation for PLW. Physiological loss in weight of leafy vegetables was observed more as compared to other vegetables. The PLW was considerably low when transported in EC vehicle as compared to traditional transport. Percent saving in PLW was observed higher (above 50 %) in fenugreek followed by tomato, coriander and okra. The maximum saving in PLW was 79.98 % in fenugreek while least 7.03 % was observed in capsicum (**Table 2**).

Shelf-life

Shelf-life of leafy vegetables was almost doubled when transported through EC vehicle. The maximum percent gain in shelf-life (200 %) was observed in cucumber while the least percent gain (16.67 %) observed in tomato over traditional transport (**Table 3**).

Conclusions

From this investigation, the following conclusions were made:

1. Freshness of fruits and vegetables were preserved at the end of the transportation as compared to those which were transported by traditional system.

2. Fruits and vegetables deteriorate easily when transported under traditional transport conditions, mainly due to high temperature and low relative humidity.

3. PLW and shelf-life of fruits and vegetables can be greatly improved by lowering temperature and increasing relative humidity during transporting.

4. It is evident that fruits and vegetables transported under evaporative cooling system could be stored for a longer period without appreciable damage than those transported under traditional system.

5. The developed system can be easily fitted on any goods transporting vehicle and removed when not required i.e. in rainy and winter season.

6. Temperature inside the chamber gradually reduces and the relative humidity gradually increases. The maximum drop in temperature was observed to be 11.0 ºC.

Ammexure: Table 4 Average data during without load test run for Figs. 3 and 4

Time of run, min	Outside conditions		Inside chamber	
	dbt, ºC	RH, %	dbt, ºC	RH, %
0	35.60	40.00	35.60	40.00
10	35.80	40.00	35.45	40.50
20	36.20	39.55	35.20	40.75
30	37.00	38.00	34.80	41.80
40	37.60	37.22	34.75	42.65
50	38.00	37.22	34.65	43.80
60	38.00	37.00	33.50	44.85
70	38.00	35.45	33.00	46.20
80	38.00	35.15	32.40	48.50
90	38.00	34.85	32.00	49.00
100	38.60	34.55	31.30	49.00
110	39.00	34.10	31.50	51.50
120	40.00	33.25	32.00	50.00
130	40.00	32.20	32.00	50.00
140	40.00	29.35	32.00	49.00
150	40.20	28.86	32.00	52.00
160	40.20	28.00	30.00	55.00
170	40.50	28.00	29.50	54.50
180	40.50	28.40	29.50	54.50
190	40.00	28.40	29.50	54.50
200	39.70	29.00	29.50	54.50
210	39.20	28.90	29.50	54.50
220	39.00	28.85	29.50	54.50
230	38.30	29.00	29.50	54.50

Ammexure: Table 5 Average data during without load test run for Figs. 5 and 4

Time of run, min	Outside conditions		Inside chamber	
	dbt, ºC	RH, %	dbt, ºC	RH, %
0	37.00	50.60	37.00	51.00
15	38.00	46.96	35.70	61.40
30	39.00	39.50	33.20	63.80
45	40.00	40.36	33.10	60.90
60	41.00	35.59	33.50	59.00
75	41.00	41.18	33.50	51.40
90	42.50	38.05	34.50	54.20
105	42.00	39.00	34.80	55.00
120	42.00	40.09	34.20	59.90
135	45.00	33.81	35.20	62.20
150	44.00	35.60	35.30	58.60
165	43.50	36.67	35.90	55.89
180	43.00	37.67	36.10	58.00
195	44.00	35.60	36.50	57.56
210	44.00	36.02	36.50	56.29
225	42.90	38.15	34.80	55.83
240	42.75	39.39	34.70	59.72
255	42.25	39.25	35.00	59.50
270	41.65	40.00	34.65	59.50

7. The relative humidity inside the chamber increasing as the vehicle progresses. Maximum increase in relative humidity was observed 55 %.

Abbreviations:

EC: Evaporatively Cooled,
PLW: Physiological Loss in Weight,
Temp.: temperature, RH-Relative Humidity

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Development and Evaluation of Carrot Harvester

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Abstract

The tractor drawn carrot harvester was designed, developed and evaluated for its performance. The carrot harvester consisted of two major components; a digging unit and a soil separation unit. The digging unit consisted of a V-shape digger blade with length and width of 350 mm and thickness of 15 mm. In soil separation unit the spacing between the rods of web was kept as 5 cm, width and length of soil separator was 700 mm, respectively. The carrot harvester was evaluated for different levels of rake angle, soil separator length and angle of soil separator. The performance parameters observed were, carrot harvesting percentage 97.8, carrot damage percentage of 4.6, soil separation index of 0.21, power requirement of 5.18 kW and field capacity of 0.21 ha/h when carrot harvester was operated at a speed of 3.8 km/h. The estimated cost of single unit carrot harvester was Rs 6,000 (≈$ 100.00) and operating cost of Rs 1,481/ha (≈$25.00). The saving in the cost of carrot harvesting was found to be 49% less than traditional harvesting. The breakeven point for the single unit carrot harvester was 148 h/year which was 52 % of annual utility and with a payback period of three years.

Keywords: carrot harvester; harvester development; cost economics; performance evaluation

Introduction

India is one of the largest producer of carrots in the world with an estimated annual production of 3.5 million tons from 0.14 million ha area (NHB 2006-07). India has achieved annual growth rate of 2.6 % in total carrot production during the last 10 years. The average yield of carrots in India is still lower than many Asian countries. Carrot is a highly perishable and need harvesting within a narrow time span, along with careful handling and proper storage before consumption or processing. In addition to the demand for local consumption, there is an increased demand of vegetables as one of the most potential commodities for exports (Kalloo, 1998). Mechanization of vegetable crops in India is very low. In general, the farmers use traditional tools and methods for cultivation of vegetable crops (Srivastava *et al*., 2009). As a result, the yields are low, cost of cultivation is high and there are huge loses ranging between 30-40 % of the total produce due to damage caused during harvesting, handling, storage, transport and processing (Srivastava, 2000).

In developing countries conventional method is still followed for carrot harvesting. The sequence practiced for conventional method are pulling of carrot from the bed, picking of dugout carrots, separation of green top from carrot, cleaning/ washing of carrot and transportation to market (cold storage). On an average, about 250-300 man-hours are required for digging and pulling out of carrots in one hectare area. Besides the quantum of labour, manual harvesting involves considerable drudgery and human discomfort. The labour has to stoop forward while digging/pulling carrots from the bed and also during picking up. Stooping posture results in a lot of bio-mechanical stresses in the back and has higher energy consumption as compared to other working positions (Hagen *et al.*, 1993). Both stooping and squatting working positions are not ergonomic and, therefore, carrot harvesting operation involves considerable human drudgery and results in higher fatigue and reduced work capabilities. Manual harvesting is not only a laborious work but also time consuming. Severely increased cost of labour has made the manual harvesting uneconomical. At times, sufficient labour is not available which delays the harvest resulting in damage to crop. The harvesting operation of carrot needs to be mechanized for time saving, reduce drudgery involved and also to reduce harvesting cost (Chaudhry *et al.*, 2000). By adopting mechanical harvesting manpower requirement was found 60 % lower as compared to manual digging, whereas crop damage was less than 2 % (Sukhwinder *et al.*, 2007). So there is a need for mechanization in root crop harvesting to reduce human drudgery and to reduce the cost of cultivation by 30-50 % with better harvesting efficiency compared to manual harvesting (Vatsa *et al.*, 1996). Very few efforts have been made to develop indigenous mechanized systems for carrot harvesting. Use of self propelled and tractor drawn equipment in vegetable crops, in India, is very dismal except in potato cultivation (Chatterjee *et al.*, 1995). Mechanical harvesters were developed only for underground crops like potato (Singh and Singh, 1979, Vatsa *et al.*, 1996, Singh and Garg, 1997), onion (Khura, 2008), groundnut (Padmanathan *et al.*, 2006, Suryawanshi *et al.*, 2008) and cassava (Gupta, 1999). Considering these facts, a tractor drawn carrot harvester was designed, developed and evaluated for its suitability in terms of performance and economics.

Materials and Methods

The tractor mounted mechanical carrot harvester was developed based on its required functions **Fig. 1**. The desired functions of carrot harvester are to dig and lift the carrots from soil and separate soil-mass from carrots and leave behind the harvester for collection with minimum damage to crop. Thus, basic components of carrot harvester were main frame, digging unit and soil separation unit. The function of each part and its development are as follows.

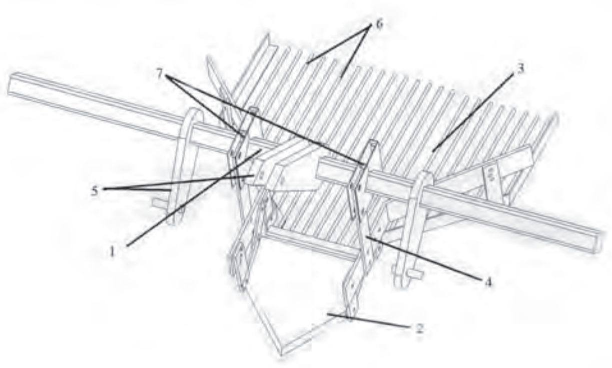
Main Frame

The main frame of the carrot harvester was developed to attach digging unit and soil separation unit with tractor three point linkage hitch system. It was fabricated from mild steel square pipe of size 65 mm × 65 mm cross-sectional area and a length of 2,000 mm. Two mild steel flats of 600 mm × 125 mm × 16 mm were mounted on the square pipe and two holes are provided on these flats to attach the frame to top link of tractor. Another two flats of 300 mm × 125 mm × 16 mm were also mounted to attach lower links of tractor (**Fig. 1**).

Digging Unit

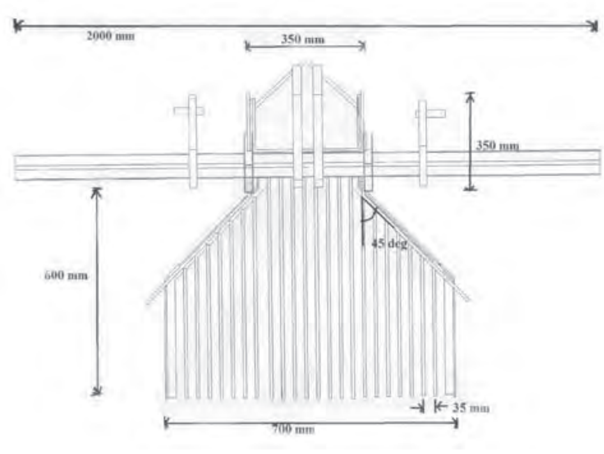
Digging unit consists of blade which digs carrot with soil-mass, lifts it and transfers it to soil separation unit. A ‘V-Shaped’ digging blade (**Fig. 2**) was designed based on the draft acting on it while harvesting of carrot. Draft on the blade while harvesting could be determined theoretically by using blade dimensions and soil and operational variables. The working depth of the blade will mainly depend upon the length of the carrots. As per

Fig. 1 Tractor drawn carrot harvester



1. Main Frame, 2. Digging unit, 3. Soil Separation unit,
4. Supporting flat, 5. Top and Bottom hitch pins,
6. Soil separator web rods, 7. Clamps

Fig. 2 Specifications of carrot harvester



the study of biometric properties of carrots the lengths were in range of 13.8-17.6 cm. So, for harvesting without damage to carrot crop the depth of operation was selected as 20 cm. The machine should dig carrots planted on raised bed having width of 0.35 m. On each bed carrots were grown in two rows at row spacing of 10 cm. Both the rows were dug simultaneously in single operation.

The draft of the share was calculated using the general soil mechanics **Eqn. 1** for a blade deforming the soil in two dimensions (Hettiarachi, 1966). Thus equation takes into account different soil properties and tool geometry parameters.

$$P_p = \gamma z_1^2 N_\gamma + c z_1 N_c + c_a z_1 N_{ca} + q z_1 N_q \text{ ....(1)}$$

Where

P_p = Passive resistance of the soil acting at an angle of soil metal friction with the normal to interface, kN per meter width

γ = Bulk density of soil, kN m^{-3}

z_1 = Depth of operation, m

c = Cohesion of soil, kN m^{-2}

c_a = Soil-interaction adhesion, kN m^{-2}

q = Surcharge pressure on soil from surface above the failure plane, kN m^{-2}

N_γ, N_c, N_q and N_{ca} are dimensionless N- factors, which describe the shape of soil failure surface and are thus function of angle of shearing resistance of soil (Φ), angle of soil metal friction (δ) and geometry of loaded interface i.e. rake angle (α). As per the optimum design values, the performance parameters were optimum at rake angle of 25º.

For determination of the draft the following assumptions were made (Khura, 2008):

i. Soil is homogenous and isotropic

ii. Average bulk density of bulk density is taken as 14.22 kN m^{-3}

iii. Soil is in friable range of moisture content with cohesion (c) 6.96 kN m^{-2}, angle of internal friction (Φ) equal to 25º and angle of soil metal; friction (δ) equal to 20º for bulk density of 14.22 kN m^{-3}

iv. The adhesion of the soil is taken as zero i.e. $c_a = 0$ assuming soil metal friction zero as soil scouring over the blade.

v. The surcharge in front of the soil above the soil failure zone is negligible i.e. $q = 0$.

Based on the above assumption **Eqn. 1** could be reduced as follows

$$P_p = \gamma z_1^2 N_\gamma + c z_1 N_c \text{ .... (2)}$$

The values of N-factor for intermediate degree of roughness of the interface could be interpolated using the following equation

$$N_\delta = N_{\delta=0} \, [(N_{\delta=\phi}) / (N_{\delta=0})]^{\delta/\phi} \text{ ......(3)}$$

Where

N_δ = the required value of the appropriate N-factors (N_δ or N_c)

$N_{\delta=0}$ and $N_{\delta=\Phi}$ = the corresponding value of the N-factor at $\delta = 0$ and $\delta = \Phi$, respectively obtained from the appropriate chart.

The following values for the different parameters in the **Eqn. 3** were used for the determination of the passive resistance of the blade.

$\gamma = 14.22$ kN m^{-3}, $c = 6.96$ m^{-2},

$\Phi = 28.58^o$, $\delta = 25.31^o$,

$\alpha = 25^o$ and $z_1 = 0.2$ m

Using the relationship shown (Khura, 2008) the value of N- factor were calculated as follows:

$N_\gamma = 1.65$ when $\delta = 0$

$N_\gamma = 1.85$ when $\delta = \Phi$

$N_c = 1.72$ when $\delta = 0$

$N_c = 1.68$ when $\delta = \Phi$

Substituting the values of N_γ and N_c determined as above, in the **Eqn. 2** the passive resistance (P_p) per unit width of the blade was obtained as 3.39 kN m^{-1}. Therefore P_p for an effective width of cut of 0.35 m of blade = 1.18 kN.

The passive resistance P_p was acting at an angle of friction (δ) with normal to the interface, hence the component parallel to the blade face (P_p) and to the blade face (P_{p1}) was given as:

$P_{p1} = 1.18 \times \cos 70^o = 0.40$ kN

and component perpendicular to the blade face (P_{p2}) was given as

$P_{p2} = 1.18 \times \cos 20^o = 1.11$ kN

The obtained value of P_{p1} and P_{p2} were used to determine the bending moment of the digger blade.

The width of the blade was decided on the basis of the width of the raised bed on which the carrots were grown in two rows. The blade was designed for its thickness on the basis of load acting on it. This could be determined theoretically analyzing various forces acting on the blade. The P_{p2} is perpendicular component of P_{p1} will cause bending moment whereas P_{p1} the horizontal component will induce direct stress in the blade. The force acted at the centre of resistance of the blade. It was assumed that the average soil resistance of the blade acts at a distance of 0.2 z_1 measured from the cutting edge (Bernacki, 1972) **Fig. 3**.

From **Fig. 3**.

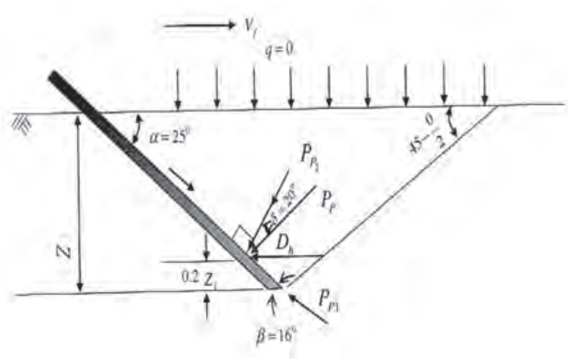
P_p = Passive soil resistance

P_{p1} = Component of P_p parallel to the blade face

P_{p2} = Component of P_p perpendicular to the blade face

D_h = Horizontal component of P_p

Fig. 3 Soil reactions acting on a simple digging share



(draft)

β = Tip angle of blade, degree

Z_1 = working dept of blade

Q = Surface pressure

δ = Coefficient of friction, degree

ϕ = Coefficient of internal friction, degree

α = Rake angle of blade, degree

V_f = forward speed of travel

Therefore, the centre of resistance was at a distance of 40 mm from the cutting edge on the central axis of the width of blade. The blade was supported on nuts and bolts at a distance of 200 mm from the cutting edge. Therefore, the distance between the centre of resistance and point of support could be determined as $200 - 40 = 160$ mm. Therefore, the bending moment due to P_{p2} will be

$B.M = 1.11 \times 0.16 = 0.18\ kN^{-m}$, and

Bending stress (σ_b) was

$\sigma_b = B.M / [(1/6).b.t^2]$ ....(4)

Where

$B.M$ = Bending moment, kN^{-m}

B = Width of blade at its point of mounting, m

t = Thickness of the blade, m

$\sigma_b = 1813.92 / [(1/6)\ 17.5.t^2] = 10919.52 / 17.5.t^2$ ....(5)

and direct stress (σ_d) due to P_{p1}

$\sigma_b = P_{p1} /b.t = 41.26 / 17.5.t$.......(6)

Total stress $(\sigma) = \sigma_b + \sigma_d$

$\sigma = (10919.32 /17.5.t^2) + (41.26 / 17.5.t)$ ....(7)

taking factor of safety as 1.2, the design stress is

$\sigma = [(10919.32 /17.5.t^2) + (41.26 / 17.5.t)] \times 1.2$ ....(8)

Equating the total stress (σ) with safe stress 58.86 MPa of mild steel, the thickness of blade (t) can be determined as follows:

$600 = [(10919.32 /17.5.t^2) + (41.26 / 17.5.t)] \times 1.2$ ....(9)

t = 15 mm.

Therefore, thickness of the blade was 15 mm and as per the requirement of digging operation width and length of 350 mm was selected. Digging blade is fabricated with mild steel sheet of 350 × 350 × 15 mm. The digging edge was cut into V- shape with an angle of 90º, angle iron of 300 × 40 × 40 × 5 mm was attached on the sides of blade for support and also provision is made to change rake angle of blade. The two mild steel flats of 900 × 60 × 10 mm are attached as side support. These both flats are used to connect the digging unit and separating unit to main frame.

Soil Separation Unit

The soil separating unit was attached just behind the blade to receive the dugout carrot and soil-mass. To separate the soil from carrots the rods are arranged in length wise along the line of travel of the harvester. The incoming crop and soil-mass was allowed to distribute by increasing the width of the separator gradually at an angle of 45º up to a width of 0.70 m (**Fig. 2**). The main body of soil separation unit is made with mild steel angle iron of 40 × 40 × 5 mm size and width of soil separator was gradually increased, angle iron was bended at 45º up to the width of 700 mm and then it is straightened. The length of soil separator was 400 mm and extra two attachments were fabricated to vary soil separator length from 400 mm to 800 mm. The spacing between the rods was kept in the range such that the carrots should not fall from this space. By the study of biometric characteristics of the carrots the diameter of the carrots are found in the range of 316 to 480 mm. To facilitate free and efficient falling of soil-mass off the separator the spacing was selected as 350 mm, it was obtained no fall of carrots through that spacing. The length of soil separator was fixed as 60 cm as per the recommended value. Similarly a provision is made to change the angle of soil separator from 0º to 20º from the horizontal plane towards ground surface. For fabrication of soil separator's web, M.S. rods of 10 mm diameter were used.

Specifications of major components were decided based on the design of the blade and soil separation unit. Digging blade and soil separator were attached to the side supporting flats and then the whole assembly was attached to main frame. Thus, complete unit of single unit carrot harvester was developed.

Experiment Procedure

The tests were conducted on the experimental farm in Division of Agricultural Engineering, Indian Agricultural Research Institute, New Delhi. Carrot cultivar 'Nantes' was planted on the raised bed following recommended agronomic practices. The soil moisture was optimized to 12 % and selected for harvesting and tractor was operated at a speed of 3.8 km/h. The carrot harvester was tested in sandy loam soil at different levels of rake angle, length of soil separator and angle of soil separator as shown below:

Rake angle (deg):

15 (R_1), 25 (R_2) and 35 (R_3).

Length of soil separator (mm):

400 (L_1), 600 (L_2) and 800 (L_3).

Angle of soil separator (deg):

0 (A_1), 10 (A_2) and 20 (A_3).

The rake angle of the carrot harvester was fixed to 15º, length of soil separator to 400 mm and soil separator angle to 0º and operated at a depth of 200 mm for 10 m distance. In the next test run again levels of machine parameters were changed. The experiment was repeated for all levels of machine parameters. The observations on performance parameters were recorded for every test run. All the test runs are replicated thrice to overcome any experimental bias.

Performance Evaluation of Carrot Harvester

The carrot harvester unit was evaluated for its performance parameters like percentage of carrot harvested, percentage of carrot damage, soil separation index, power requirement and field capacity.

Percentage of Carrot Harvested

It is the ratio of the number of carrots successfully harvested to the total number of carrots present in the given area of the experimental field.

Percentage of carrot harvested, % = (No. of carrots succesfully harvested / total number of carrotsin the field) × 100

Percentage of Carrots Damaged

It is the ratio of the number of carrots damaged due to harvesting process to the total number of carrots harvested.

Damage percentage, % = (No.of carrots damaged / Total number of carrots harvested) × 100

Soil Separation Index

Soil separation index of single unit carrot harvester was worked out based on the following expression.

Soil separation index = W_c / W_t

where,

W_c = weight of soil and carrots collected at the rear end of the soil separating unit, kg

W_t = theoretical weight of soil that was cut by blade along with carrots at a constant depth, kg

Cost Economics

The bill of material of the carrot harvester was prepared along with estimated cost of fabrication and total cost of carrot harvester. The cost of operation obtained was compared with common practice of mechanical harvesting and manual harvesting of carrot. The total cost of operation was determined as sum of the fixed and variable cost. The breakeven point and payback period were computed for carrot harvester.

Breakeven Point

$BEF = FC / (CH - C)$

Where,

BEP = Breakeven point, h/year

FC = Annual fixed cost, Rs/year

CH = Custom hiring charges, Rs/h

C = Operating cost, Rs/h

CH = (C + 25 % over head) + 25 % profit over new cost

Payback Period

$PBP = IC / ANP$

Where,

PBP = Payback period, year

IC = Initial cost of machine, Rs

ANP = Average net annual profit, Rs/year

$ANP = (CH - C) \times AU$

and,

$AU = AA \times EC$

Where,

AA = Average annual use, h/year

EC = Effective capacity of machine, ha/h

Table 1 Specification details of carrot harvester

Name	Specification
Power source	Tractor
Width of operation, mm	350
Depth of operation, mm	200
Digging blade dimension (L x B x H), mm	350 × 350 × 15
Length of soil separator, mm	600
Width of soil separator, mm	700
Diameter of rods used in soil separator, mm	10
Spacing between the rods, mm	350

Table 2 Performance of carrot harvester at different combinations of machine parameters

Machine parameters combination	Carrot harvested (%)	Carrot damaged (%)	Soil separation index	Power requirement (kW)
$R_1L_1A_1$	96.40	6.26	0.32	4.51
$R_1L_1A_2$	96.54	5.97	0.29	4.34
$R_1L_1A_3$	96.56	5.54	0.26	4.29
$R_1L_2A_1$	96.53	6.86	0.24	4.74
$R_1L_2A_2$	96.69	6.48	0.23	4.56
$R_1L_2A_3$	96.39	5.89	0.22	4.45
$R_1L_3A_1$	96.95	6.57	0.23	4.51
$R_1L_3A_2$	96.97	6.36	0.22	4.37
$R_1L_3A_3$	96.98	6.31	0.21	4.22
$R_2L_1A_1$	97.19	4.68	0.32	5.24
$R_2L_1A_2$	97.41	4.55	0.29	5.11
$R_2L_1A_3$	97.66	4.35	0.26	5.05
$R_2L_2A_1$	97.46	5.72	0.24	5.31
$R_2L_2A_2$	97.51	5.48	0.23	5.20
$R_2L_2A_3$	97.79	4.75	0.21	5.16
$R_2L_3A_1$	97.18	5.41	0.24	5.23
$R_2L_3A_2$	97.19	5.08	0.23	5.15
$R_2L_3A_3$	97.27	4.90	0.22	5.08
$R_3L_1A_1$	97.21	4.31	0.33	5.70
$R_3L_1A_2$	97.33	4.33	0.30	5.61
$R_3L_1A_3$	97.39	3.99	0.26	5.57
$R_3L_2A_1$	97.30	4.97	0.26	5.80
$R_3L_2A_2$	97.36	4.81	0.24	5.50
$R_3L_2A_3$	97.41	4.45	0.22	5.36
$R_3L_3A_1$	97.11	5.11	0.26	5.70
$R_3L_3A_2$	97.16	4.99	0.25	5.53
$R_3L_3A_3$	97.27	4.86	0.24	5.43

Results and Discussion

The prototype carrot harvester was developed and its detailed specifications are given in **Table 1**. The performance of the unit was evaluated in terms of percentage of carrot harvested, percentage of carrot damage, soil separation index and power requirement (**Table 2**).

The percentage of carrot harvested was significantly affected by rake angle. The percentage of carrot harvested increased with increase in rake angle from 15º to 25º and at 35º only marginal increase was observed. The influence of soil separator angle and length of soil separator was less pronounced in all combinations of rake angle. The successful harvesting percentage increased from 96.2 to 97.7 % when rake angle increased from 15º to 35º for all combinations of angle of soil separator and length of soil separator. In general, for a given angle and length of soil separator, percentage of carrot harvested increased with increase in rake angle. This might be due to better penetration achieved at increased rake angle. The percentage of carrot damaged increased with increase in length of soil separator and decreased with increase in rake angle and soil separator angle. This was due to increase in travel time of carrot on soil separator as soil separator length increases. The rake angle of 35º yielded the less percentage of carrot damaged but there is no large difference when compared to 25º. The percentage of carrot damaged increased from 4.87 to 5.51 % as length of soil separator increases from 400 to 800 mm and decreased from 6.86 to 4.63 % as rake angle increased from 15º to 25º. Angle of soil separator doesn't affected carrot damage significantly.

After digging of carrots the soil was to be separated from carrots with the help of soil separating unit. For better separation of soil from carrots the value of soil separation index should be as low as possible. All three lengths of soil separator gave comparable performance at given rake angle and angle of soil separator. The soil separation index increased initially with increase in length of soil separator and later remained almost same. The average minimum soil separation index of 0.21 was obtained with 600 and 800mm length of soil separator followed by 0.26 with 400 mm length. This might be due to as length of soil separator increases, retention time for separating soil from carrots on the soil separating unit increases. At the same time angle of soil separator also showed significant effect on separation index. As the soil separator angle increased from 0° to 20°, soil separation index decreased from 0.27 to 0.23. This was observed because as the angle of soil separator increased flow ability of soil in separator unit increased and soil agitation would be good to obtain good soil separation. The rake angle of carrot harvester doesn't show any significant effect on the soil separation index.

Power is the main constraint for any digging operation. Power requirement will depend upon the depth of operation, soil metal friction and tool geometry. The power requirement steadily increased with increase in rake angle and had very small change with increase in length and angle of soil separator. Only rake angle had significant affect on the power requirement. The average power requirement at 15º, 25º and 35º rake angle was 4.44, 5.3 and 5.57 kW with all combinations of length of soil separator and angle of soil separator. Power requirement increased as rake angle increased, this might be due to increase in draft of the harvester unit. The draft of the unit increased because of increase in soil resistance as the increase in rake angle increased the soil contact area and the soil metal friction (Harrison, 1982).

The best combination of parameters was at 25º rake angle, 600 mm length of soil separator and 20º angle of soil separator. At this combination, percentage of carrot harvested was 97.6 %, percent of carrot damage of 4.56 %, soil separation index of 0.21 and power requirement was 5.18 kW. The field capacity of carrot harvester was found to be 0.21 ha/h and field efficiency was 78.9 %.

Cost Economics

Bill of materials was calculated based on dimensions and total cost of fabrication of carrot harvester unit calculated as Rs. 6,000. The cost involved in mechanical carrot harvesting, by considering both prime mover and carrot harvester was calculated and compared with cost of manual harvesting. The breakeven point of carrot harvester was calculated along with payback period.

Fixed cost of tractor, Rs/h	= 103.5
Variable cost of tractors, Rs/h	= 190
Fixed cost of carrot harvester Rs/h	= 5.6
Variable cost of carrot harvester, Rs/h	= 11.25
Cost of operation of carrot harvester with tractor, Rs/h	= 311
Cost involved in manual harvesting Rs/ha	= 2,925
Cost involved in mechanical harvesting of carrots, Rs/ha	= 1,481
Saving cost, %	= 49.3
Breakeven point, h/year	= 147.8
Breakeven point, ha/year	= 31.03
Payback period, years	= 2.53
Time saving percent	= 96

Conclusions

The developed carrot harvester was efficient and economically viable for harvesting carrot crop with 49 % and 96 % saving in cost and time respectively, compared to traditional method. At 25º rake angle, 600 mm length of soil separator and 20º angle of soil separator was best combination and operated at

12 % soil moisture given maximum carrot harvesting of 97.6 %, carrot damage of 4.6 %, soil separation index of 0.21 and power requirement was 5.18 kW. The cost of the carrot harvester was Rs.6,000, had a breakeven point at 148 ha and payback period of three years.

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Decision Support System for Estimating Operating Costs and Break-Even Units of Farm Machinery


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Abstract

Farm machinery costs make up a significant part of the operating and overhead costs of any farm operation. If the capital invested in a machine is to be used efficiently, that machine must be used over enough hectares or for enough hours to have costs comparable to or below custom hiring rate. This paper presents a decision support system (DSS) for calculating the total operating cost and break-even units of farm machinery. The guidelines given in IS 9164 (1979) were followed for estimating operating cost of farm machinery. The DSS leading to computer software developed in Visual Basic™ programming provided the intuitive user interfaces by linking databases such as useful life of the implement/machine in years and hours and percentage of accumulated repair cost to support the decision on custom hiring of farm machines. The application of DSS was demonstrated to calculate the operating cost and break-even units for custom hiring of combine. It was concluded that the DSS can be used effectively in calculating the operating cost of farm machinery and in suggesting break-even units for custom hiring of farm machines.

Keywords: Decision support system, farm machinery, operating cost, break-even units

Introduction

There has been a progressive shift from draft animal power (DAP) to mechanical power in Indian agriculture because DAP and manual labour are not sufficient to cope with the work load of intensive agriculture. The use of mechanical power is becoming indispensable for making an optimal use of other resources and in-time completion of various farm operations under intensive agriculture. Mechanization saves time in completing different farm operations, which gives the crop more time to mature; allows the farmer to be more flexible in his farming operations; and facilitates multi and relay cropping. This transition from animal power to mechanical power in some states has made the agriculture capital intensive. But, it has played a key role in modernization of Indian agriculture due to its benefits of improved labour efficiency and productivity, efficient use of expensive farm inputs, reduction of human drudgery and timeliness of farm operations.

The recent structural changes in economic environment, liberalization policy and the signing of general agreement on tariff and trade have laid down new challenges in which, India has to compete in the international trade including agricultural trade. The basic requirement of this competition is to reduce the unit cost of production, and improve quality of agricultural produce so as to meet the international standards. The cost of production can be reduced only if the cost of every single factor contributing towards the total cost is minimized and resource productivity maximized. Therefore, the agricultural strategies need to be based on the time-tested principles of business management and entrepreneurship so that agriculture can be made a profitable venture (Sharma *et al.*, 2007).

The cost of farm machinery is the single largest input after land and buildings. Farm machinery costs make up a significant part of the operating and overhead costs of any farm operation. If the capital invested in a machine is to be used efficiently, that machine must be used over enough hectares or for enough hours to have costs comparable to or below the same operation being done by a custom operator. Agricultural engineers and economists use a variety of engineering and economic principles in calculating a machine's use and costs. An effective farm manager must also know these principles and apply them when deciding to buy, rent or share machinery (Schuler, 2005).

The most accurate method of determining machine costs is complete records of the actual costs incurred. Estimating costs is an alternative. When estimating costs, methods that require more data specific to the situation, the more accurate becomes the estimate. Singh (2012) examined economics of farm mechanization and suggested some policy measures –the total use of the farm machinery, which on an average is much less than the prescribed norms. Therefore, there is need to enhance its productive use as a result of which, the fixed cost can be reduced significantly.

Schuler and Frank (2012) provided farm managers with an additional and more accurate tool for their management decisions permitting input of data specific to the operation. A series of tables and two worksheets, one for tractors and one for other machines, were developed to help estimate machine costs using the ASABE data and formulae. Once the machine's costs are estimated accurately, one can make decisions regarding purchases, leases, rentals and sharing the machinery. Lazarus (2009) estimated farm machinery operation costs calculated via an economic engineering approach. The data are intended to show a representative farming industry cost for specified machines and operations.

Sharma *et al.* (2007) reviewed the status and future of custom hiring in India in the backdrop of changing world agriculture. They observed that the custom hiring got a boost with the onset of green revolution in mid 1960s and gained importance mainly due to rise in the cropping intensity and drop in average land holding. They concluded that farm mechanization would continue to be on the forefront and presented the impact of further fragmentation of landholding due to rising population of India, government policies of diversification and evolution of new farm machines on prospects of custom hiring.

Machinery and equipment expenses represent a major category of cost in crop production. Purchasing equipment with the use of loans from financial institutions or equipment manufacturers has been the typical method of obtaining machinery services for most farm operations. Producers are increasingly considering other options for obtaining machinery services due to increasing equipment costs, obsolescence of owned equipment and limited sources of outside debt capital.

A method of estimating machinery costs over several time periods is needed to compare the options of using custom hire services or purchasing equipment. This paper presents a decision support system (DSS) for calculating the total operating cost of farm machinery so that one can determine whether or not it makes economic sense for him to own a machine by calculating the break-even units for implements as well as power source.

Theoretical Considerations

Operating Cost of Farm Machinery

The cost of using farm machinery consists of expenses for ownership and operation, and overhead charges. Ownership costs are independent of use and are often called as fixed costs. Costs for operation vary directly with the use and are referred to as variable costs. The guidelines given in IS 9164 (1979) are followed for estimating cost of farm machinery operation. The total operating cost of farm machinery is the sum of fixed costs, variable costs and overheads.

Fixed costs

The fixed costs for a farm machinery include depreciation, interest on investment, insurance and taxes (property, registration and road); and housing.

Table 1 Useful life of some of the commonly used farm machinery (IS 9164, 1979)

Name of machine	Useful life		
	Hours	Years	Hour/year
Stationary engine	10,000	10	1,000
Electric motor	15,000	15	1,000
Power tiller	8,000	10	800
Tractor (wheeled and crawler)	10,000	10	1,000
Combine (self-propelled)	3,000	6	500
Combine (mounted and drawn)	2,000	7	286
Seed drill	2,500	10	250
Seed-cum-fertilizer drill	2,000	8	250
Planter	2,000	10	200
Plough	3,000	10	300
Disc harrow	3,000	10	300
Cultivator	4,000	10	400
Front-mounted dozer attachment for wheeled tractor	3,000	10	300
Towed scraper for wheeled tractor	2,000	10	200
Power sprayer (knapsack and tractor mounted)	2,000	8	250
Seed cleaner	2,500	5	500
Agricultural trailer	3,600	12	300
Power thresher	2,500	8	313
Centrifugal pump	10,000	10	1,000
Power chaff cutter	5,000	8	625
Rotavator	2,400	8	300
Ridger	1,500	12	125
Blade terracer	2,000	10	200
Puddler	2,500	10	250
Cane crusher	10,000	10	1,000

Depreciation: This cost reflects the reduction in value of a machine with the use (wear) and time (obsolescence). While actual depreciation would depend on the sale price of the machine after its use. The depreciation can be estimated by different computational methods. The following formula based on straight-line method is used in the study.

$D = (P - S) / L$

where,

D = depreciation cost, Rs. per year

P = purchase price of the machine, Rs.

S = residual value of the machine, Rs. and

L = useful life of the machine, years

The depreciation cost per hour can be calculated by dividing D by the number of hours the machine is expected to be utilized in a year. Residual value of the machine (S) may be taken as 5 % of the purchase price. Useful life of some of the commonly used machines (L) under general conditions of usage is given in **Table 1**.

b) Interest: Annual charges of interest is calculated on the basis of the actual rate of interest payable. If this information is not available, 12 % of average investment is taken. Average investment (A) over the life of machine is calculated by the formula:

$A = (P + S) / 2$

Insurance and Taxes: Actual amount paid or to be paid annually for insurance and annual taxes, if any is charged. If the information is not available, it is calculated on the basis of 2 % of the average investment (A) over the life of machine.

Housing: It is calculated on the basis of 1.5 % of the average investment (A) over the life of machine.

Variable costs

The variable costs for farm machinery include cost of fuel, lubricating oil, repair and maintenance charges, and wages and labour charges.

Fuel: Fuel consumption depends on the size of the power unit, load factor and operating conditions. The actual fuel consumption can be observed while the machine is working or may be taken from the results obtained at official testing stations. It is a common practice to consider average fuel consumption from the varying load test as approximately equal to fuel consumption on the farm. Average fuel consumption can also be estimated by the formulae:

a) $A = 0.15 \times B$

where

A = average diesel consumption, l/h

B = rated power, kW

b) $C = 0.25 \times B$

where

C = average petrol consumption, l/h

Oil: The actual oil consumption should be recorded while the machine is working. In case oil consumption data are not available, oil consumption may be taken as 2.5 to 3.0 % of the fuel consumption on volume basis.

Repair and Maintenance: Repair and maintenance expenditures are necessary to keep a machine operable due to wear, part failure, replacement of tyres and tubes and accidents. The costs of restoring a machine are highly variable. Normal wear deterioration is directly related to use, and restoration or repair costs are assumed to be typical variable costs. The cost of filters, replacement of oil and other lubricants are also included under repairs and maintenance. Maintenance costs, primarily those related to lubrication, are directly related to use also.

The accumulated repair and maintenance costs (TAR) at any point in a machine's life can be estimated from the following formulas:

For four-wheel drive and crawler tractors: $TAR = 0.100X^{1.5}$

For stationary power unit and two-wheel drive tractor: $TAR = 0.120X^{1.5}$

For self-propelled combine, dozer and scraper: $TAR = 0.096X^{1.4}$

For agricultural trailer: $TAR = 0.127X^{1.4}$

For pto-driven combine, seed drill, seed-cum-fertilizer drill and sprayer: $TAR = 0.159X^{1.4}$

For seed cleaner: $TAR = 0.191X^{1.4}$

For plough, planter, harrow, ridger and cultivator: $TAR = 0.301X^{1.3}$

Where,

TAR = total accumulated repair cost divided by purchased price of the machine expressed as percentage, and

X = 100 times the ratio of the accumulated hours of use to the wear out life given in **Table 1**.

The repair and maintenance cost may also be taken as percentage of purchase price for usable life in years as given in **Table 2** (IS 9164, 1979).

Wages and Labour Charges: In performing custom work, the cost of at least one operator has to be included. Sometimes an assistant may also be engaged. One or both of them may be employed on a yearly basis, and the yearly cost of the operators is equal to the wages paid plus any allowances to which they may be entitled. Average cost per hour may be computed by dividing the total cost by the number of hours the operator has performed the work. This cost is, of course, higher than the average per hour work on the farm because part of the time will be used for traveling, interruptions and moving machines from one farm to another, and this is not paid for directly by the customers.

Overhead charges

This includes charges for supervision and establishment and interest on working capital if applicable. It should be assumed as 20 % of the sum of fixed and variable costs.

Total cost per hour

The sum of fixed cost, variable cost, and overhead charges per hour shall give the total cost per hour.

Calculating the cost of custom hire

Table 2 Percentage of accumulated repair cost of farm machinery (IS 9164, 1979)

Name of machine	Cost in percentage of purchase price for usable life in year									
	1	2	3	4	5	6	7	8	9	10
Stationary engine	3.8	10.8	19.8	30.3	42	55.5	70.3	86.4	102.6	120
Electric motor	2	5.8	10.7	16.5	23	30.1	38.4	46.7	56.1	65.3
Power tiller	3.8	10.8	19.8	30.3	42	55.5	70.3	86.4	102.6	120
Tractor (wheeled and crawler)	3.2	9.0	16.5	25.3	35	46.2	58.6	72	85.5	100
Combine (self-propelled)	4.9	13	23	34.3	46.8	60.6	-	-	-	-
Combine (mounted and drawn)	6.6	17.3	30.4	44.8	61.9	80	100.3	-	-	-
Seed drill	4	10.5	18.6	27	38.9	49	60.9	73.4	86.5	100.3
Seed-cum-fertilizer drill	5.5	14.4	25.4	38	52.5	67	83.2	100.3	-	-
Planter	6	14.8	29	36.4	48.7	61.6	75.4	88.7	104.4	119.8
Plough	6	14.8	29	36.4	48.7	61.6	75.4	88.7	104.4	119.8
Disc harrow	6	14.8	29	36.4	48.7	61.6	75.4	88.7	104.4	119.8
Cultivator	6	14.8	29	36.4	48.7	61.6	75.4	88.7	104.4	119.8
Dozer	2.4	6.4	11.2	16.9	22.9	29.6	36.8	44.3	52.3	60.6
Scraper	2.4	6.4	11.2	16.9	22.9	29.6	36.8	44.3	52.3	60.6
Power sprayer	5.5	14.4	25.4	38	52.5	67	83.2	100.3	-	-
Seed cleaner	12.6	33.2	58.9	87.3	120.5	-	-	-	-	-
Agricultural trailer	2.5	6.5	11.5	17.2	23.8	30.4	37.7	45.4	53.6	63.4

services

Many farmers do not choose or cannot afford to own all the machinery required in their farming operations. Often this is because of restricted capital, limited labour, and small size of land holdings or other reasons. For these farmers, the purchase of custom services (paying someone else to pay for plough, plant, fertilize, and harvest) is one method of obtaining the needed machinery services on the farm. To decide whether it is more economical to own machinery or to hire a customer operator, compare the fixed and variable costs of owning and operating the machinery to the total costs of custom service. The break-even (BE) units are calculated using the formula (Gutierrez & Dalsted, 2008):

$$BE = F / (S - V)$$

where:

BE = break-even units, h or ha

F = annual fixed costs, Rs.

V = variable costs per unit, Rs./h or Rs./ha and

S = custom charge per unit, Rs./h or Rs./ha

Development of the Decision Support System (Dss)

A Decision Support System (DSS) was developed for calculation of operating cost of agricultural prime movers and machinery based on IS 9164 (1979). The DSS also calculated break-even units for custom hiring of farm machinery. It was developed using Visual Basic 6.0 as front end and Microsoft Access as back end. There were several sequential screens to complete the process and get the desired output. The developed screens were very intuitive and easy to select the parameters and enter the expected values wherever required. The DSS started with splash screen and followed by selection screen for selection of implement/machinery or power source or both for calculation of operating cost of farm machinery and ended with the final result required by the user.

The complete DSS was divided into two modules. The first module calculated the operating cost of agricultural prime mover and machinery and the second module calculated the break-even units for custom hiring of farm machinery or power units. The modules were further divided into the sub-systems such as database sub-system and model sub-system of the DSS.

Database Sub-system of the DSS

The database sub-system consisted of data pertaining to 25 commonly used farm machines (**Tables 1** & **2**) in Indian agriculture. The tables had information about agricultural implements, prime movers, name of machine, useful life of the machine in years and hours and data on percentage of accumulated repair cost of farm machinery. The database on machines had provision for adding useful life of a new farm machine and editing any parameter value of the entered data in the database. The brief description of database subsystem is as follows.

Useful life of farm machines

The database had data on useful life in hours and years for commonly used 25 farm machines (**Table 1**).

Repair and maintenance cost of farm machinery

The database on repair and maintenance cost had data on percentage of accumulated repair cost for 17 farm machines (**Table 2**). It had cost in percentage of purchase price of a machine for different years of useful life of the machine.

Model Subsystem of the DSS

In this system, two modules were developed for calculation of operating cost of agricultural prime mover and farm machinery and for calculation of break-even units for custom hiring of farm machinery.

Operating cost of farm machinery

An algorithm leading to computer software in Visual BasicTM was developed for calculation of operating cost of farm machinery. The flow chart of the programme for calculation of operating cost of farm machinery is shown in **Fig. 1**. The considered variables for calculation are depreciation, interest, insurance, fuel cost, repair cost, labour etc.

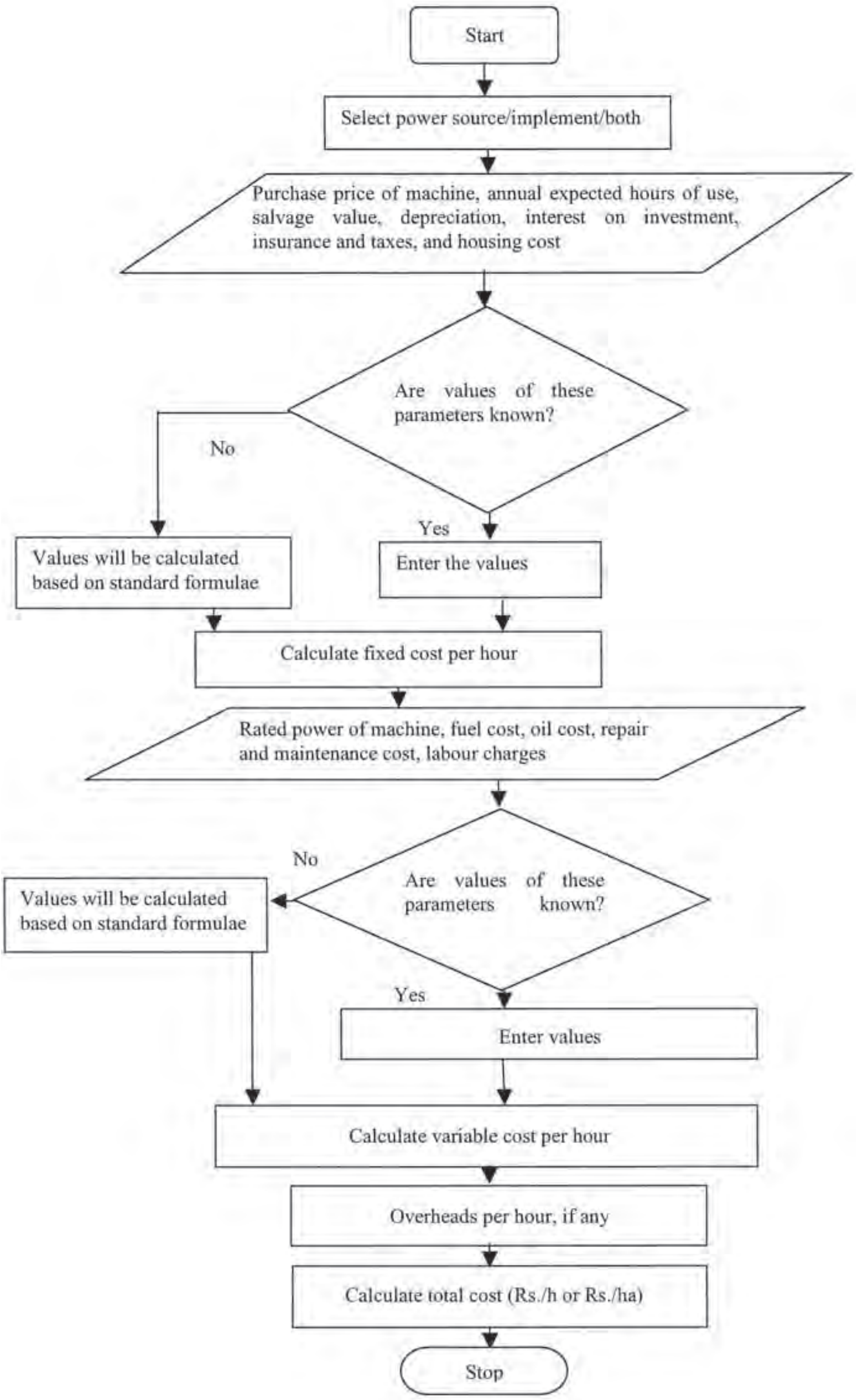
The fixed cost of a farm machinery included depreciation, interest, insurance and taxes, and housing. The screen of DSS for calulation of fixed cost of a farm machinery is shown in **Fig. 2**. The name of selected machinery appeared in the text box and purchase price and expected use of machine were entered by the user. The DSS processed these data with the help of two options i.e. pre-defined standard formula (default values) and user defined parameters.

The variable cost for the selected implement/ machinery or power source included fuel cost, oil cost, repair and maintenance, and wages and labour charges. The variable cost may be calculated by entering known values or by clicking on the 'input' button through already fed formulae (**Fig. 3**). The repair cost in percentage of purchased price for whole usable life of the machines was calculated by the DSS based on formula as per IS 9164 (1979).

Break-even units for custom hiring of farm machinery

An algorithm leading to computer software in Visual BasicTM was developed to find out the break-even units for custom hiring of farm machinery based on the custom charges per unit, fixed annual cost, variable cost per hour and data on operating hours on own farm as well as on others farms. The flow chart of the programme is shown in **Fig. 4**. The DSS calculated break-even units of farm machine in hour or ha based on standard equation (**Fig. 5**).

Fig. 1 Flow chart for calculation of operating cost of farm machinery



Application of the Developed DSS

The case considered to validate the developed DSS for calculating the total operating cost of farm machinery and for calculating the break-even points for combine harvester (93 kW) is presented in this section. The costs of diesel and oil were taken as Rs. 40/l and Rs. 150/l (1 US$ = Rs. 56), respectively for calculation of operating cost of combine. The wages of the driver was taken as Rs. 200 per day (8 h). The total operating cost of the combine was calculated by DSS for varying purchase price of combine from Rs. 1.2 to 1.4 million at an interval of 0.1 million and annual hours of use from 300 to 500 h at an interval of 50 h. The variation in fixed and variable costs of the combine is shown in **Fig. 6** and values are given in **Table 3**. It was observed that fixed and variable cost of the combine increased with increase in purchase price of the combine and decreased with increase in annual hours of use. The decrease in fixed cost of the combine was sharp with increase in annual hours of use from 300 to 500 h. Similar trend was observed for total operating cost of the combine (**Fig. 7**). However, the decrease in variable cost of combine was gradual with increase in annual hours of use from 300 to 500 h. Therefore, it may be concluded that the annual hours of use significantly affected the fixed and total operating costs of the combine.

The break-even units in hour of combine was also calculated using DSS (**Fig. 5**) for varying custom

Fig. 2 Calculation of fixed cost of combine using DSS

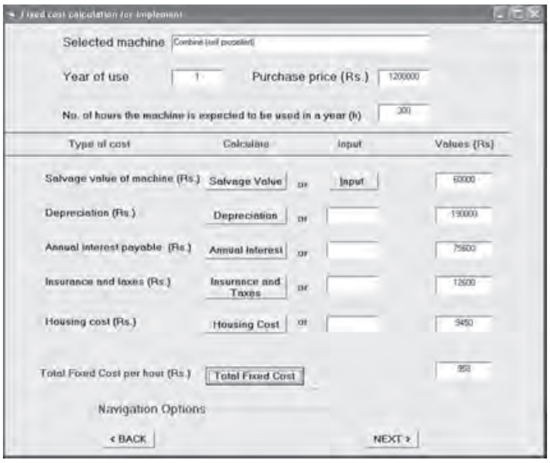


Fig. 3 Calculation of variable cost of combine using DSS

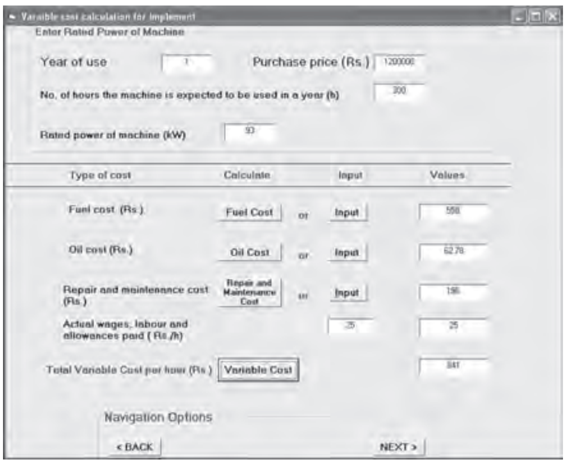


Fig. 5 Calculation of break-even units of combine using DSS

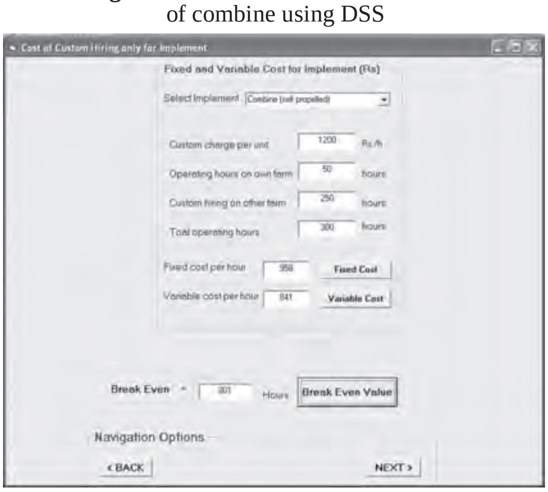
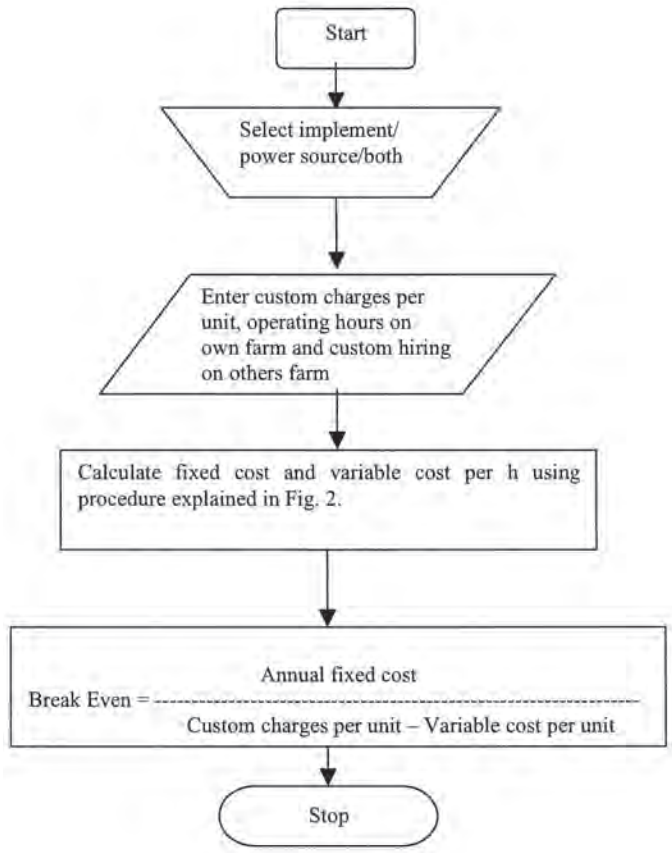


Fig. 4 Flow chart for calculation of breakeven units for custom hiring of farm machinery



hiring rates of Rs. 1200, 1350 and 1500/h for varying hours of use from 300 to 500 h and results are shown in **Fig. 8**. It indicated that break-even units reduced with increase in custom hiring rates from Rs. 1200/h to Rs. 1500/h and with an increase in annual use of combine from 300 to 500 h. **Table 3** also shows that break-even units decreased from 436 to 390 h with increase in annual use of combine from 300 to 500 h for combine costing Rs. 1.2 million at custom hiring rate of Rs. 1500/h. Similar trend was observed for purchase price of combine of Rs. 1.3 and 1.4 million and custom hiring rates of Rs. 1200 and Rs. 1350/h. Therefore, it may be concluded that break-even units should be more than 436 h for combine costing Rs. 1.2-1.4 million for custom hiring rates of Rs. 1500/h. Therefore, it may be concluded that custom hiring rates significantly affected the break-even units of combine.

Fig. 6 Variation of fixed cost (FC) and variable cost (VC) of combine for different purchase price and annual use

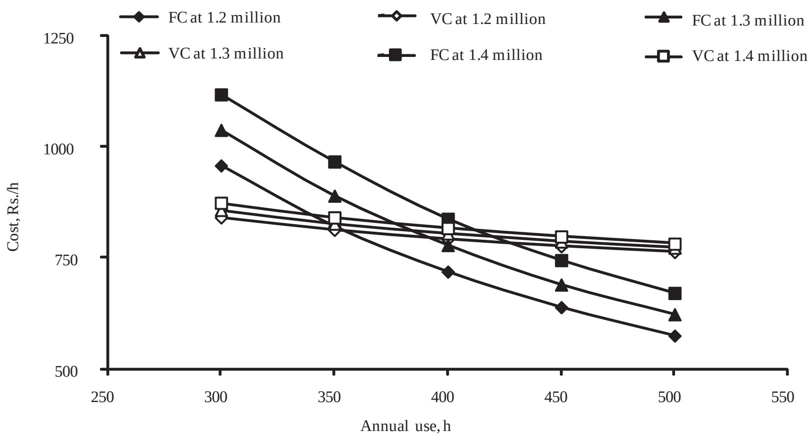


Fig. 7 Variation of total operating cost (TC) of combine for different purchase price and annual use

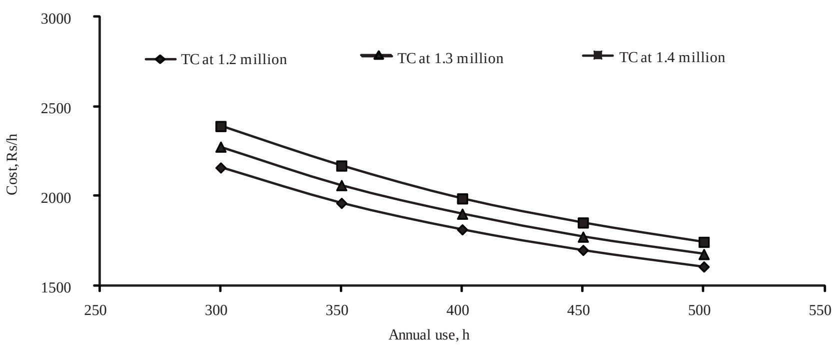
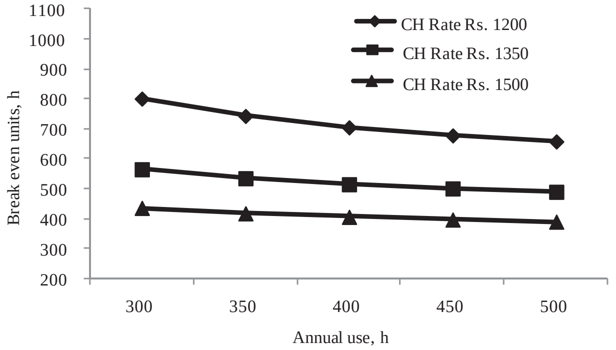


Fig. 8 Variation of break even units of a combine (Rs. 1.2 million) for different custom hiring (CH) rates and annual use



Conclusions

The following conclusions can be drawn from the study.

1. The DSS helped in calculation of operating cost and break-even units of farm power unit alone or with an implement for varying hours of use of the machine and at varying purchase price of the machine.
2. The validation of the DSS with a case study shows its effectiveness in estimation of operating cost of farm machinery and calculation of break-even units for custom hiring service.

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Table 3 Break-even units for custom hiring of combine for different custom hiring rates and purchase price of combine

Purchase price of combine, Rs.	Expected hours of use, h	Cost, Rs.			Breakeven units (h) at different custom hiring rates (Rs./h)		
		Fixed	Variable	Total	1,200	1,350	1,500
1,200,000	300	958	841	1,258	801	565	436
	350	821	813	1,171	743	535	418
	400	719	792	1,119	705	515	406
	450	639	776	1,089	678	501	397
	500	575	763	1,075	658	490	390
1,300,000	300	1,038	858	1,338	911	633	485
	350	890	827	1,240	835	596	463
	400	779	805	1,179	789	572	448
	450	690	787	1,140	752	552	435
	500	623	773	1,123	730	540	428
1,400,000	300	1,118	874	1,418	1,029	705	536
	350	958	841	1,308	934	659	509
	400	838	817	1,238	875	629	491
	450	745	798	1,195	834	607	478
	500	671	782	1,171	803	591	467

Note: 1 US$ = Rs. 56.00

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Biomass Conversion for Energy Carriers: An Analytical Review on Future Issues for Rural Applications in India

by

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Abstract

Indian agriculture in the rural sector uses a mix of energy resources for production and post harvest operation. The use of renewable energy resources from biomass has not duly picked up due to non-availability of appropriate energy conversion technologies and due to their uncompetitive prices as compared to commercial energy resources. The agriculture sector of the country has been continuously facing shortage of electric supply and petroleum products at distant locations in many areas. Energy generation from biomass in decentralized mode in the rural catchments would be a prominent route to meet the gap between demand and supply. The rural energy scene and primary energy consumption in India reveal that there are wide research gaps to go ahead in the area of biomass conversion techniques viz., bio-chemical conversion of biomass, gas utilization, thermo-chemical conversion of biomass, bio-diesel, and alcoholic fermentation. The paper reviews various methods of biomass conversion technology to meet the energy consumption of Indian agriculture to keep pace with the food grain production demand for the ever growing population and the scope of energy conversion and utilization to rural livelihood.

Key words: energy carriers, biomass conversion, fermentation, biodiesel, energy generation

Introduction

India over time has been increasingly dependent on commercial energy. The country is still dependent on import to meet about 79 percent of requirement of crude oil. The shortage of electric energy for peak demand is about 11 percent. On the other hand, the energy demand of the country is expected to grow at 5 percent and projected to be among the highest in the world due to sustained economic growth, rise in population, rise in income levels and increased availability of goods and services. Present trends suggest further increase in energy consumption with many parts of the country shifting to more energy intensive agriculture for increased productivity. The trend in primary energy consumtion in India is given in **Table 1**. India is privileged with abundant biomass resource potential of 23 GW, yet it harvests small proportions, with fundamentally different deployed policies and articulated strategies (Rajbeer and Andri, 2013). Scope of energy conservation through proper uses of resources and machinery exist to a large extent. Some estimates suggest energy savings up to 30 percent in the agricultural sector. Agricultural processing units also consume large quantities of electricity and petroleum products for which systematic information is not available. Rural processing, mostly small and individual entrepreneurships, are more inclined to locally available energy resources.

Although energy scenario in India to-day bears a reflection of growing dependence on conventional energy yet around 32 percent of total primary energy supply in the country is still derived from biomass and more than 70 percent of the country's population depends upon it for its energy needs. **Table 2** provides main characteristics of the energy used in rural areas. If biomass was to be substituted by LPG or other petroleum products, India would need to import an additional more than 30 million tonne of such products, which may cost US$ 7000 million per year.

With food production target of 300 million tonne by 2020 with major thrusts on primary and secondary processing in food products, better living conditions with increasing income; the energy demand of rural India is also to increase many folds on a medium-term perspective. Energy generation from biomass in decentralized mode in the rural areas would be a prominent route to meet the gap between demand and supply.

Energy Conversion Technologies

Bio-Chemical Conversion of Biomass

Biomass essentially is a product of photosynthesis and it would not be inappropriate to define it as a natural solar cell (**Table 3**). About 1.5 tonne of crop residue is harvested with each tonne of main product. Off-farm use of crop residue remains limited. Stagnation or reduction in demand of crop residues and increase in its productivity is resulting in the burning of large quantity of dry crop residue every year. Apart from destruction of a good source of organic matter and energy, uncontrolled burning of crop residue creates a serious environmental problem which will get aggravated as more crop residue become surplus each year. The chemical composition of crop residues is not much different than wood. Authoritative studies reveal that the forest cover of the country is depleting every year at a rate more than 1.5 million hectares.

The biogas plant digested slurry (BDS) is richer in organic matter and NPK contents compared to farm yard manure (FYM) and vermincompost as given in **Table 4** (Liangwei *et al.*, 2012). A large number of field trials on utilization of BDS for production of cereals, oilseeds, vegetables and floriculture and on various other activities have been carried out at different centres in India during the last about 20 years period (Gunaseelan, 2004). Important conclusions of these trials are as follows:

- BDS, in general, replaced 50-75 percent of recommended doze of inorganic N-fertilizer without significantly affecting the grain yields of wheat, paddy, maize and sorghum crops.
- About 50 percent of N-fertilizer requirement of black-gram, groundnut and soybean crops was substituted with BDS without significantly affecting grain yield. In case of soybean and mustard up to 100 percent substitution was possible.
- BDS replaced 25-50 percent of the N-fertilizer requirement of ladies

Table 2 Indian rural energy scene

Feature	Characteristics
Non commercial energy use as percentage of total primary energy	80 %
Total use of firewood	223 MT
Use of animal dung and agro-waste	130 MT
Estimated per capita biomass used for cooking	1.0 -1.6 kg/day of firewood equivalent
Households using electricity for lighting	43.5 %
Households using kerosene for lighting	77 million
Per capita electricity use in rural areas	150 unit/year (Guesstimate)
Per capita electricity use in urban areas	1500 unit/year (Guesstimate)
Average per capita electricity use in India	590 unit/year
Additional LPG required to be imported if fuel wood/ wastes were to be substituted by it	30 MT

Table 1 Primary energy consumption in India

Source	Unit	1990-91	1995-96	1998-99	1999-00	2000-01	2001-02	2002-03	2011-12
Petroleum products	MT	57.75	77.91	94.26	102.63	106.97	110.96	111.07	211.42
Natural Gas	BCM	12.77	20.93	25.71	26.89	27.86	28.04	29.97	46.48
Coal	MT	211.73	270.13	292.27	299.97	309.63	322.61	336.52	535.88
Lignite	MT	13.77	22.14	23.42	22.12	22.95	24.81	26.10	41.88
Hydro Electricity	Bill. unit	73.90	72.60	82.60	80.50	74.30	73.90	63.80	75.58
Nuclear Electricity	Bill. unit	6.10	7.90	12.00	13.30	16.90	19.30	19.20	41.20
Renewable based electricity	Bill. unit	-	-	-	-	-	-	10.00	14.50
Non-commercial	MT								
Firewood		-	-	-	-	-	-	223.00	130.00
Animal Waste		-	-	-	-	-	-	310.00	150.00

MT: million tonne; BCM: billion cubic metre finger, tomato, chilly, potato and brinjal crops without significantly affecting fruit yield.

- Application of BDS along with inorganic fertilizers for crop production resulted in better soil health by maintaining higher microbial population than by use of fertilizers alone.
- Limited experiments carried out revealed utility of the BDS in various other activities such as rooting medium in horticultural crop, cultivation of Azolla and blue green algae, fish rearing, as animal feed and mass production of bio-control agents.

Researchable Areas

- Development of processes and technology for enhancing biogas production during lower temperature months.
- Adoption and modification of processes for quicker anaerobic digestion of cellulosic rich substrates.
- Durable and low cost alternate materials for biogas plants for digesters and gas storage systems.
- Development/adoption of gas engine operating on biogas for electricity generation for rural applications.
- Development of slurry handling technologies for dewatering of biogas spent slurry and recycling of filtered water for community biogas plants.
- Modification and adoption of processes for production of nutritionally enriched organic manure utilizing rural, semi-urban and industrial solid wastes.
- Adaptive field trials of various technologies and appliances for their technical soundness and socio-economic feasibility and new application of biogas.

Alcoholic fermentation: The process of alcohol production by fermentation using the enzymes of yeast is as old as human civilization. Alcohol was the fuel used when IC engine was invented. It was soon replaced by petroleum fuel which was available in abundance at much lower price. Gasohol, which is a blend of gasoline and alcohol, has been found to be a much cleaner fuel than gasoline and has been used extensively in automobiles without any modification in the combustion system of SI engines. It has higher octane value and antiknock properties than gasoline and burns slowly, coolly and completely resulting in reduced emissions. Brazil is pioneer in blending up to 24 percent ethanol with gasoline. Government of India has also implemented blending of 5 percent of ethanol with gasoline used as automobile fuel. While it is true that any biomass containing carbohydrates can be considered as feedstock for alcohol production, the yield of alcohol per tonne of individual feedstock varies considerably. Feedstock for alcohol production can be classified into 3 main categories, viz., i) those containing starch, ii) those containing sugar, and iii) those containing cellulose. The technology for ethanol production from starchy biomass such as corn grain is being widely practiced in USA and Brazil (Dhussa and Jain, 2002). Sweet sorghum is a special type of sorghum whose grain and stem can be used for production of sugar, alcohol, syrups, jaggery, feed and fodder. Its stalks have a greater potential if used as raw material for fuel ethanol production. National Research Centre for Sorghum, Hyderabad has shown that the fermentation of juice from sweet sorghum variety SSV-84 yielded 4.5 kL of ethanol per ha. However, the high fermentation efficiency of 91 percent was observed in another variety Keller (Rao *et al*., 2004). A pilot plant study showed that all the costs incurred in the ethanol production from sugarcane molasses and sweet sorghum stalk were equal except raw material cost which was more in case of the sweet sorghum as given in **Table 5** (Rao *et al.,* 2004). A liter of ethanol from sweet sorghum costs Rs 0.56 more than ethanol from sugarcane molasses. If sugarcane molasses is available locally then the difference is higher by about Rs 3.86/l. The study, however, revealed that the sweet sorghum can be conveniently adopted as substrate for ethanol production in the existing distilleries.

Kim and Dale (2004) estimated annual biomethanol production potential from major crops, corn,

Table 3 Estimates of biomass in India

Item	Estimated by-product, million tonne
Rice	181.84
Wheat	86.12
Sorghum	23.37
Pearl millet	33.40
Maize	53.20
Other cereals	23.09
Bengal gram	6.89
Pigeon pea	9.20
Lentil	1.86
Other pulses	7.04
Groundnut	7.93
Rapeseed and mustard	10.08
Soybean	5.86
Sunflower	1.46
Other oilseeds	1.96
Cotton	27.30
Jute and Mesta	3.15
Sugarcane	84.01
Potato	1.22
Onion	0.45
Coconut	7.56
Cashew nut	0.47
Total	523.44 MT

Table 4 Nutrient status of microbially degraded swine slurry (Liangwei *et al*., 2012)

	Raw slurry	Digested slurry
Nitrogen (N %)	0.1040	0.300
Phosphorus (P_2O 5 %)	0.0504	0.168
Potassium (K_2O %)	0.0693	0.189
Total nutrient [(N + P_2O 5 + K_2O) %]	0.2240	0.657

barley, oat, rice, wheat, sorghum and sugarcane (**Table 6**). The ligno-cellulosic biomass available from these crops could produce 442 GL/ year of bioethanol. Asia is the most favourable region which can produce 291 GL of bioethanol because of biomass availability. Results indicate that rice straw is potentially the most favorable feedstock and the next most favorable raw materials are wheat straw, corn stovers and sugarcane bagasse in terms of quantity of biomass available. Rice straw, wheat straw and corn stovers are the most favorable bio-ethanol feedstock in Asia (Amrita Ranjan, *et al.,* 2013).

Biodiesel: India presently imports nearly 70 percent of its crude petroleum requirement and the import bill is now touching about US$ 18,000 million, which is roughly 30 percent of its total imports. In view of the ever-increasing consumption (40 mt/year), cost escalation and impending uncertainties of diesel availability, search for alternative fuels for at least 10 percent substitution of petrol-diesel in the short term, and more subsequently, by alternative fuels has assumed critical importance in India. Among prominent renewable bio-fuels used in IC engines are ethanol, producer gas, biogas and plant oils (María, *et al.*, 2014). During the last two decades, a major breakthrough has been made in the use of transesterified plant oils and animal fats popularly known as bio-diesel, as a partial or complete substitution of petro-diesel. Presently, biodiesel occupies a unique position among the renewable bio-fuels as it is ideally suited for use in a diesel engine. Rapeseed-oil-methyl-ester was the first type of bio-diesel fuel produced commercially in 1988. Even though research on the use of crude vegetable oils was started in India in the mid fifties, work on the use of transesterified oils was started only during mid eighties.

Research Gaps

- Work on collection of germplasm, identification of high yielding and fast growing species of potential feed-stocks as well cultivation practices for agro-forestry for production of biodiesel need to be accelerated, which is crucial to the success of biodiesel production and adoption in India.
- Apart from planting the potential feed stocks on degraded and waste lands, farmers need to be encouraged.
- Work on utilization of by products of transesterification such as glycerol and use of oil cakes need to be pursued.
- Diesel engine manufacturers should treat bio-diesel at par with HSD.
- Guidelines for blending of bio-diesel with petro-diesel (splash blending) need to be formulated.

Table 5 Cost of production of ethanol

Particulars	Sweet sorghum, (Rs./L)	Sugarcane molasses, (Rs./L)
Man power	0.50	0.25
Steam	1.00	1.00
Electricity	1.00	1.00
Yeast	0.10	0.10
Management, etc	0.10	0.25
Pollution control measures	Nil	0.25
Raw material	10.41	6.40 - 9.70
Total	13.11	9.25 - 12.55

Table 6 Composition of residues and potential ethanol yield of crops

Crop residues	Dry matter (%)	Lignin (%)	Carbohydrates (%)	Ethanol yield (L/kg of dm)
Rice straw	88.0	7.13	49.33	0.28
Wheat straw	90.1	16.00	54.00	0.29
Bagasse	71.0	14.50	67.15	0.28
Corn stover	78.5	18.69	58.29	0.29
Sorghum straw	88.0	15.00	61.00	0.27

Thermo-Chemical Conversion of Biomass

The thermo-chemical conversion involves thermal degradation through directed chemical reactions under controlled reaction conditions, **Table 7** (Faisal, *et al.*, 2014).

Combustion involves direct burning of biomass to get heat. This is a process in which the biomass is degraded at higher temperatures to char and volatiles, which in turn are oxidized with the excess oxygen provided. A large amount of heat of reaction is released along with formation of carbon dioxide and water as gaseous emittants. Gasification is carried out in sub-stoichiometric oxygen atmosphere at temperatures ranging from 700 to 1,000 ºC. The final product, called as the ‘producer gas’, is a low or medium calorific value fuel gas, depending on the medium of gasification. The gasifiers are used to substitute fuel oil in furnaces and in engines for power generation (Arnsfeld, *et al.*, 2014).

Researchable areas

A suitable device for continuous feeding of biomass for large size plants

- Tar decomposition and separation from the gas before its use to IC engine applications. Thermal cracking and physical separation of tar still need attention to commercialise the technology
- Development of hot gas cleaning system for application in high temperature fuel- cell
- Development of gas scrubber for low-temperature fuel gas utilisation applications

• Integration of gasification system to gas engine for power generation
• Development of an efficient charring system and briquetting machine for the preparation of solid fuel.
• Development of technology for making the briquettes suitable for gasification

Conclusions

The following recommendations may be considered for adoption and implementation with respect to biomass conversion in India:

Following field scale technologies, now available in the country, need support by way of tax concessions, interest free loan, technical support and subsidy in cost of procurement, etc.

• Family size fixed dome type biogas plants for solid-state anaerobic digestion of cattle dung (field tested designs are now available).
• Institutional and community biogas plant for kitchen and dining hall waste.
• Biphasic bio-methanation system for vegetable market waste.
• Biogas plants for agro-industrial solid waste and effluent specifically for cottage and small scale industries processing farm produce.
• Gasifier for generation of producer gas for thermal and power application
• Provide libral grants for carrying out R&D activities in and on-site demonstration of large systems for solid-state anaerobic conversion of crop residues for decentralized rural power supply.
• Massive R&D support should be provided to develop and demonstrate technology for alcoholic fermentation of crop residues to fuel ethanol as a partial substitute of IC engine fuel particularly petrol.

Satisfactory field scale technologies are now available for bioconversion of animal dung, crop residues, aquatic weeds and solid waste and effluent generated from agro-industries to energy rich gas and nutrient rich manure. Keeping in view enormous environmental benefits (land, water and air) that accrue to the nation, the union and provincial governments should encourage implementation of bio conversion technologies for treatment of effluent and solid waste generated from production, handling, marketing and processing activities of the farm produce at all levels.

Table 7 Thermo-chemical conversion technologies

Technology	Primary product	Applications
Pyrolysis		
Fast pyrolysis	Liquid	Liquid fuel and chemicals
Carbonization	Charcoal	Solid fuel
Slow pyrolysis	Gas	Fuel gas
	Liquid tar	Liquid fuel, chemicals
	Solid char	Solid fuel
Liquefaction	Liquid	Oil and liquid fuel
Gasification	Gas	Synthesis gas and fuel gas
Combustion	Heat	Heating

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Development and Testing of Pedal Operated Wild Apricot Pit Grader




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Abstract

A wild apricot pit grader having a capacity of 100 kg of wild apricot pits per hour has been fabricated and evaluated at the Department of Post Harvest process and Food Engineering, G.B. Pant University of Agriculture and Technology, Pantnagar, India. The unit consisted of outer angle iron frame, feed hopper, screening unit, bicycle assembly, bearings etc. Grader grades the wild apricot pits in four grades of A (> 12 mm), B (11-12 mm), C (10-11 mm) and D (< 10 mm) and obtained at discharge outlet of four screening trays having varying screen aperture size. Grading of the pits was done according to the variation of the thickness of individual pits. The average capacity of the pedal operated wild apricot pit grader was 100 kg/h. The average grading efficiency of grader was found to be 79.60 %. Breakage percentage of pits during operation of grader was negligible. The cost of operation of wild apricot pit grader was determined and found to be Rs. 1.00 per kg of pits. The cost of grader was Rs. 5,200 only and Pay-back period calculates as 0.47 years.

Introduction

Apricot (*Prunus armeniaca. L*) is an important fruit crop of mid hill and dry temperate regions of India. Apricot is an important temperate fruit and perishable in nature. Each and every part of apricot is either consumable or usable as ingredients in different health and food products. Globally, apricot is grown with its two cultivars, sweet apricot and wild or bitter apricot.

Globally, Turky, Iran, Italy, France, Pakistan, Spain, China and USA are leading producer of apricot. In Asia apricot firstly cultivated in North-Eastern China. Wild apricot appears to be indigenous to India. In India, apricot is grown commercially in the hills of Himachal Pradesh, Jammu and Kashmir, Uttarakhand, Uttar Pradesh and to a limited extent in north eastern hills and in Nilgiris (Chadha, 2009).

Global, production of fresh apricot is between 2.2 and 2.7 million tons/year. Sweet and wild apricots are cultivated in Uttarakhand about an areas of 9,100 hectares with the annual production about 30,576 tons (Anonymons, 2007). Sharmagz Kaisha, Moorpark, Turkey, St. Ambrose are mostly cultivated verities of wild apricot in Uttarakhand and mainly utilized for the extraction of the apricot kernel oil used for various medicinal purposes.

Wild apricot kernel is a rich source of oil (54.21 %), protein (17.75-22.56 %), carbohydrate (21.16-35.26 %), crude fibre (0.84-4.71 %) and dietary fibre (6.03-22.24 %). wild apricot oil is effectual massage oil for aged and dry or irritated skin (Anon, 2003). It has ability to penetrate the skin without leaving an oily feel. While massaging applying warm apricot oil mixed with a pinch of common salt on chest gives relief to patients with acidity. Also oil owing to the presence of tocopherols (630 μg/g) can find place in many cosmetic preparations (Guner *et al*., 1999).

Wild Apricot harvesting, cracking and oil extraction are still carried out manually in India, especially in mountainous area of Uttarakhand state, which results in increased cost and processing time for kernel extraction and also tedious and time consuming process. Therefore, a mechanized cracking, handling and expelling unit is required to save the time and labour. But the lack of proper pit grading equipment is one of the major problems for the further development in mechanized process after harvesting (Gupta and Sharma, 2009). As the perfect grading of apricot pit is the most critical and delicate step for efficient decortication for achieving high-quality kernels after decortication there was a great need to develop a efficient wild apricot pit grader

As the raw wild apricot pit was collected directly from the farmers for further post harvest process it was always beneficial and economical to farmers to sale their commodity after grading in different grades. The farming and farmers cultivated wild apricot is mainly belongs to mountainous area Himalaya, So there has been great demand for developing wild apricot pit grader which provide the on-farm grading, easy for transport for field to field and can be operated with proper energy sources at remote places. The major objective of to develop a pedal operated wild apricot pit grader working on the principle of "grading of pit according to the variation in individual pit thickness" having the highest grading efficiency and it gives the required grades of pit which is suitable for the various machines in the post harvest process line of wild apricot pit and suitable for on-farm conditions.

Materials and Methods

The main components of manually pedal operated wild apricot pit grader **Fig. 1** are as follows:

Outer frame: It supports all the parts of the grader and is fabricated of mild steel angle iron of size 25 × 25 × 3 mm. the force transmitted is uniformly distributed in all the parts and reduce the vibrations. The stresses developed in the frame were far below the allowable shear and compressive stress. Maximum length of the grader formed by angle frame was 1,730 mm and maximum width was 340 mm.

Feed hopper: The feed hopper of conical shape with square cross section made of mild steel sheet (IS-2062). The thickness of sheet used for fabrication was 2 mm. The hopper was 400 × 400 mm square opening at the top while 30 × 30 mm square opening at the bottom. The hopper is divided in to two sections for its side view upper 50 mm height section was rectangular while lower 380 mm height section was trapezoidal. The feed hopper was placed on the top of the angle frame and at the 100 mm above the top surface of top most screen for avoiding the chocking during feeding. The inclined side of the hopper was at an angle of 69 degrees to the horizontal to facilitate free flow of pit from its bottom opening. This angle should be greater than the angle of repose of pit on metallic surfaces.

Grading Screen Assembly:

Frame: It consisted of mild steel angle iron of size 25 × 25 × 3 mm. It supports the all four grading trays of the screen and fixed at their proper position.

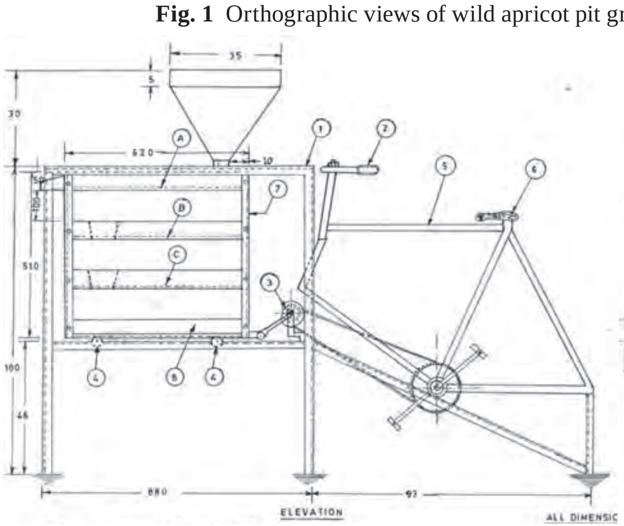
Trays (**Fig. 2**): There are three grading trays and one bottom tray acts as a pan and all of this made of galvanized iron sheet having thickness 5 mm. The screen opening called as aperture was rectangular in section and length of all apertures on each screen was same and it was 20 mm. Width of openings on one single screen was the same, but it was reduces from top to bottom grade screens by 1 mm. Bottom pan had no openings and it just collects the smallest grade of material. After grading we get the A (> 12 mm), B (11-12 mm), C (10-11 mm) and D (< 10 mm) grades of wild apricot pits.

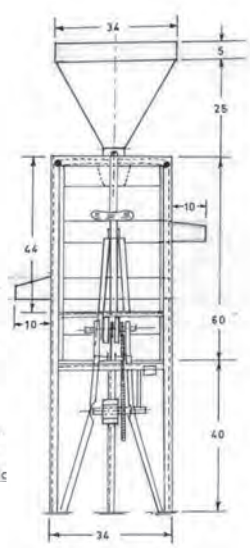
Bearings: Four bearings were provided at each bottom corner of the frame angle which provide the to and fro motion of the whole grading screen assembly.

Bicycle Frame:

Handle: To reduce the drudgery in operations a mild steel pipe of size 13 mm was provided at the front of

Fig. 1 Orthographic views of wild apricot pit grader, cm





1. Outer frame, 2. Handle, 3. Sprocket, 4. Bearing, 5. Cycle frame, 6. Seat, 7. Sieve unit, 8. Tray

Fig. 2 Fabricated pedal operated wild apricot pit grader

the grader. The operator holds the pipe, which makes working of the grader simpler and comfortable.

Cycle frame: Cycle frame made of solid pipes (mild steel) of 25 mm diameter were provided for holding the weight of the operator.

Seat: A standard size leather seat as used in bicycle was provided to reduce discomfort to the operator.

Pedal operated chain drive: A chain drive transfer the human power from pedal to the “to and fro” motion of the screen assembly via eccentric drive arrangement for convert the rotational motion of the sprocket to the “to and fro” motion of screens (IS-6813).

Tray (**Fig. 2**) *outlets:* Outlets for each individual screens were welded for discharging the properly graded pits in the receiver. Each outlet has square in section with length of 100 mm and width 75 mm. Position of the outlet on top screen was at the forward end of screen while it was right, left and bottom of the second, third and pan screens respectively, and this arrangement for just easy to attaching the receiver bags.

The dimensions, material used and other some detail of the prototype model were mentioned in **Table 1**.

Evaluation of the Prototype Grader

Tests were conducted on the developed grader to evaluate the grading efficiency and the output capacity of the machine to grading the pits (Khan, *et al.*, 2006). The experiment carried out at triplicate manner which increases the accuracy of evaluation. As the grader was pedal operated manual power is the source of power and considers an individual man can work continuously for 4 hrs. During the testing moisture content of the wild apricot pit was 12.5 % (w.b) and rpm of the pedal was 75 rpm. There is need of at least three labours during operating a grader one for driving the pedal of machine and other for feeding and collecting the graded samples of wild apricot pits. Anthropometric data of some important characteristics of the working labours are recorded which includes height 161 ± 5.0 cm, weight 60 ± 10 kg, BMI (Body Mass Index) 20.2 ± 2.0 and MUAC 28.0 ± 2.0 cm (Annamma and Sabiha, 1994) (**Fig. 3**).

Determination of Grading Efficiency

Grading efficiency was calculated by measuring the outputs collected from outlets of each of the screen outlets (Sahay and Singh, 2010). The grading efficiency of the grader was calculated by the following equation:

Grading efficiency (%) = $\{$Weight of sample taken-$[x^1 + (x^2 + y^1) + (x^3 + y^2) + y^3]$ / weight of sample taken$\}$ × 100

where,

x_1 = Undersize pits retained in tray (A), g

x_2 = Undersize pits retained in tray (B), g

x_3 = Undersize pits retained in tray (C), g

y_1 = Oversize pits retained in tray (B), g

Table 1 Important specifications of the wild apricot pit grader

Particulars	Specifications
Length, mm	1,730
Width, mm	340
Height, mm	1,035
Weight, kg	65
Cost, Rs.	5,200
Material used	MS sheet, angles, bicycle frame
No. of persons	3
Screen sizes, mm	12 11 10 PAN
Shape of the holes	Rectangular
Capacity, Kg/h	325
Grading efficiency, %	79.60
Breakage, %	Nil

y_2 = Oversize pits retained in tray (C), g

y_3 = Oversize pits retained in tray (PAN), g

Capacity

Output capacity of the grader was calculated by following formula:

Output capacity, kg/h = Weight of graded material collected from outlet of each screen, kg / Time required for complete grading, hr

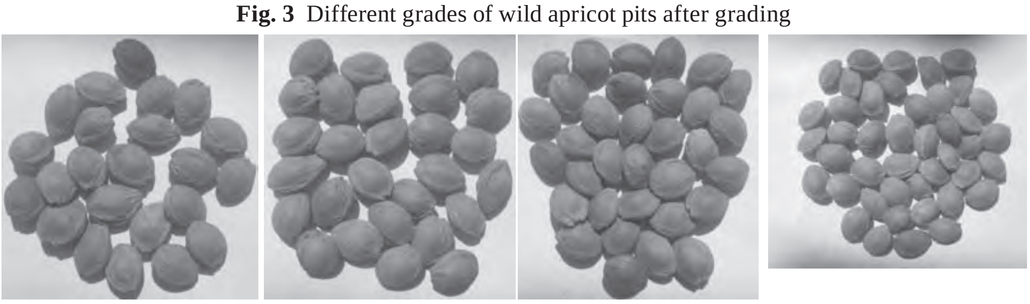
Pay-Back Period

The payback period focuses on recovering of the cost investment. It represents the amount of time taken for a capital budgeting project to recover its initial cost. The payback period of the wild apricot pit grader was determined and measured in years (Newnan 1983).

$$I_d = B\{[(1 + i)^n - 1)] / [(i(1 + i)^n)]\}$$

where,

Fig. 3 Different grades of wild apricot pits after grading



Grade A Grade B Grade C Grade D

B = Annual net investment benefits, Rs.
I_d = Initial investment, Rs.
i = Interest rate, %
n = payback period, years

Result and Discussion

The wild apricot pit grader was tested with wild varieties of the apricot collected from Tehari Gadhawal region of Uttarakhand state of India. The experiment was replicated three times and the average values were reported. Five hundred grams of wild apricot pits were used during each test. The performance of the machine was tested at following constant parameters:

Pedal RPM = 75 rpm
Test batch size = 0.5 kg

The following data were collected during testing.

Weight of pits collected through outlet of each tray, separately.

Weight of seed remained in bottom PAN tray.

Amount of undersize, oversize and proper size of pits in collected sample.

The **Table 2** give performance of the wild apricot pit grader for collected wild apricot pits. Maximum grading efficiency observed was 80.88 % whereas minimum grading efficiency was 78.54 %. Average grading efficiency observed was 79.60 %. During the experimentation grader gave the average capacity of 100 kg/h.

Cost Evaluation

The cost of operation of the prototype model of grader was estimated. From the calculations made, it is seen that the capacity of the newly developed wild apricot pit grader is 100 kg of pits per hour. The cost of operation of wild apricot pit grader was determined and found to be Rs. 1.00 per kg of pits. The time required for the grader to grade one kg of pits was 0.60 min whereas; by manual method it is not possible to grade the pits with accuracy. Payback period of this developed model of wild apricot pit grader was 0.47 years.

Conclusions

The present work was undertaken to develop a pedal operated wild apricot pit grader to grade wild apricot pits into four different sizes and to study its economic feasibility. Accordingly, a grader was designed, developed and tested. The capacity of the grader in the laboratory was 100 kg/h. Grading efficiency of the grader was 79.60 %. The development cost of the wild apricot pit grader was Rs. 5,200 ($1 US ≈ Rs. 60) while pay- back period of the grader was 0.49 years. This grader was best suited for the hilly area, on-farm efficient grading of the wild apricot pit grader and basic need for the all post harvest mechanical processing of the pits.

Table 2 Grading efficiency of the pedal operated wild apricot pit grader

Screen No.	Retained weight, g	Undersize, g	Oversize, g	Proper size, g	Grading efficiency, %
I	104.836	9.749	-	95.087	79.381
II	69.309	2.363	9.549	57.397	
III	99.288	10.989	11.966	76.333	
PAN	226.567	-	58.479	168.088	
I	90.325	11.651	-	78.674	78.542
II	46.006	5.472	5.664	34.87	
III	122.368	10.963	17.462	93.943	
PAN	241.301	-	56.078	185.223	
I	129.217	27.028	-	102.189	80.888
II	63.805	3.482	9.949	50.374	
III	97.544	2.039	12.792	82.713	
PAN	209.434	-	40.267	169.167	
Average					79.603

Table 3 Cost evaluation of wild apricot pit grader

Particulars	Unit	specification
Cost of grader	Rs.	5,200
Life of grader	year	8
Annual use	hour	600
Annual fixed cost		
Depreciation	Rs/year	850
Interest (12 %)	Rs/year	824
Repair and maintenance	Rs/year	312
Total	Rs/year Rs/h	1986 3.31
Operating cost		
Fuel	Rs/h	Nil
Lubricant	Rs/h	1
Labour (Rs. 200/day)	Rs/h	75
Total	Rs/h	76
Total cost	Rs/h	79.31
Cost of grading (for 100 kg/h capacity)	Rs/kg	0.80
Processing cost	Rs/kg	1.00
Net benefit	Rs/kg	0.20
Payback period	year	0.47

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An Experimental Determination of the Specific Soil Resistance of a Sandy Loam Soil Using Vertical Soil Tillage in the Northeast of Mexico

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Abstract

An investigation was carried out to determine the specific soil resistance using a chisel plough prototype for vertical soil tillage in the semi-arid region of the northeast of Mexico. For this a combination of an axial transducer and an integral soil force dynamometer were used with a capacity of 60 and 80 kN of draft, respectively. The equipment for force measurement was developed and calibrated in the facilities of the Department of Agricultural Engineering of the Agrarian Autonomous University Antonio Narro, Mexico. Fourteen (14) arrangements of chisels plough were evaluated and divided into three blocks, for vertical tillage, with and without expanding wings to two different working depths. In the arrangements of the first block of tests, the performance of a chisel with three sizes of wings against two chisels to a depth of 0.20 m was compared. The results showed that there were no significant differences in the specific resistance of the soil, with an average of 83 kNm^{-2}. In this first block of evaluations, a reduction of specific resistance of 30 % was obtained with the use of a chisel with any size of wings in comparison with a chisel without wings to a depth of 0.30 m (from 121 to 82 kNm^{-2}). In the second block of tests, the arrangement of two leading chisels to 0.20 m working depth with a rear chisel to 0.30 at 0.45 m with 0.45m width size wing in comparison with two leading chisels to 0.20 m and a chisel without wings showed a significant difference in the specific resistance from 73 to 84 kNm^{-2} respectively. In the third block, two rear tines with wings to 1.20 m of spacing were evaluated. The lowest specific soil resistance was obtained with the use of 0.60m width size wings in comparison with the other wing geometries with values from 84 and 100 kNm^{-2} respectively.

Introduction

In the production of extensive grain crops, the soil preparation is the agricultural practice that represents the highest unitary costs on farm production and the one that consumes the biggest amount of fossil fuel. At the present time, due to the increasing cost of fossil fuels, the reduction of the prices of the agricultural commodities and environmental pollution, have required a progressive reduction of production cost and to search technological alternative solutions that substitute the traditional agricultural production systems. According to different studies carried out and with the appropriate agricultural productions systems, a 30 % decrease can be obtained in the fuel consumption (IDAE, 2006).

Nowadays, due to the excessive and inadequate use of the tillage implements, soil degradation is caused and it generates reduced profitability of the farm crops. Searching for solutions to this problem has led to the study and installation of farm tillage conservation systems, including soil vertical tillage, with the purpose of diminishing the impact on the environment and especially on the soil. For these reasons, it is important to know different operating parameters of tillage implements and their effect in the soil (Camacho and Rodriguez, 2007).

It is convenient to point out that the vertical tillage is a technology that promotes the saving of energy demand of farm production costs and improves the physical properties of the soil in comparison with the use of other traditional primary tillage. The vertical tillage is a new cultivation practice in the world which tends to replace the traditional systems such as moldboard or disks plough. It has been demonstrated that the agricultural production systems based on the use of chisel plow require up to 40 percent less energy and working time that the traditional systems, without reducing the grain yields (Michel *et al.*, 1985).

McKyes (1985) described that a critical working depth was reached with chisel ploughs, in which lateral removal of soil was avoided, and that depended on the working width and tine rake angle, as well as density and moisture content of soil. To work deeper of critical depths, it is advisable the use of lateral wings coupled to the chisels tip, which reduces specific soil resistance and increase the working width and field efficiency.

Cisneros *et al.*, (1998), after four years of tests, evaluated the effect of winged chisel tines on the specific soil resistance and bulk density. The results showed a significant reduction of those parameters in depths shallower than 0.25 m in comparison with treatments of direct seeding. After thirty months of experimental soil loosening test conducted by Di Prinzio *et al.*, (1999), which consisted of combining a subsoiler with wings together with two shallow leading tines compared with a traditional chisel plough, a significant reduction of soil density was found.

On the other hand, Di Prinzio *et al.*, (2001), compared the use of a winged subsoiler against a normal subsoiler and found a significant difference of 17.4 % in the reduction of soil density. Similar results were found by Spoor and Godwin (1978), using two geometries of wings compared with a conventional subsoiler.

The purpose of the present work was to evaluate and to determine the energy requirements of vertical tillage, by means of the application of the principle of critical depth and the use of an integral transducer for measurement draft, applied to different arrangements of chisels (working depth and number of tines) plough with and without wings and also to determine the magnitude of disturbed cross section and specific soil resistance.

Materials and Methods

The experiments were carried out during the years 2010 to the 2012 at the experimental field station, “Rancho Navidad”, of the Agrarian Autonomous University Antonio Narro, located to the northwest of the state of Coahuila, Mexico. The location of the site is 25º01'50.88"N and 100º37'35.65"W, with an altitude of 1884 MASL. The soil is a sandy clay loam with 47.5 % sand, 45 % silt and 6.8 % clay. The average soil gravimetric moisture content for cultivations was 12 %. The total size of the experimental test plot was three hectares divided into 14 treatments with eight replicates of 100 meters long by 2 meters wide. For the statistical analyses, a design of totally randomize blocks was used.

For recording the resistance forces of the soil during the field work, two force transducers were used, an axial type with capacity of 60 kN, placed between the two tractors. The other transducer was an integral type with capacity of 80 kN (**Fig. 1**), and placed between the tractor and implement (**Fig. 2**).

Fig. 1 Integral force transducer employed during field evaluation of a prototype for vertical tillage

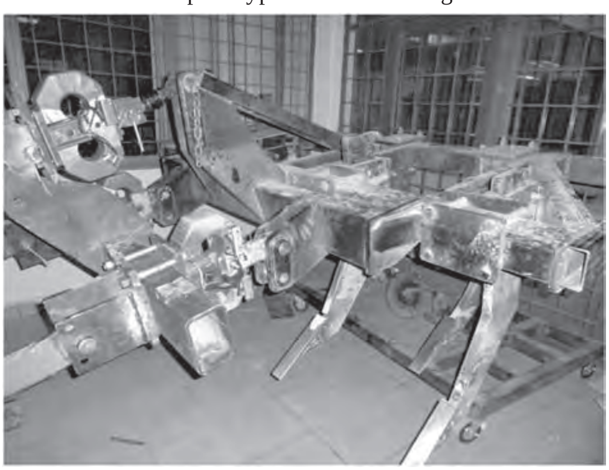

Fig. 2 Apparatus set for field evaluation, showing the integral force transducer

Table 1 Evaluated set of blocks Arrangement of chisel tines under field conditions

Group	Arrangements	Wing's Size (m)	Description
I	1RCT-30	*	Chisel tine without wings
	1RCT-SW-30	0.30	Winged chisel tine
	1RCT-MW-30	0.45	Winged chisel tine
	1RCT-LW-30	0.60	Winged chisel tine
	2ST-20	*	Two shallow tine at 0.20 m depth
	2ST-30	*	Two shallow tine at 0.30 m depth
II	2ST20-1RCT30-SW	0.30	Two shallow tine at 0.20 m with rear chisel
	2ST20-1RCT30-MW	0.45	Two shallow tine at 0.20 m with rear chisel
	2ST20-1RCT30-LW	0.60	Two shallow tine at 0.20 m with rear chisel
	2ST20-1RCT30	*	Two shallow tine at 0.20 m with rear chisel
	2ST30-1RCT30	*	Two shallow tine at 0.30 m with rear chisel
III	2RCT30-SW	0.30	Two rear chisel at 1.20 m spacing
	2RCT30-MW	0.45	Two rear chisel at 1.20 m spacing
	2RCT30-LW	0.60	Two rear chisel at 1.20 m spacing

* Chisel tines without wings. Note: The depth of rear chisel tine remains constant at a depth of 0.30 m.

For collecting test information, a IOTECH brand system of data acquisition 200 was used together with a signal conditioner DBK-43A. For the analysis of information of the recorded magnitude forces, the method of spectral analysis (Campos and Wills, 1995) was applied. For the analysis as well as for the interpretation of the results, the statistical package of Minitab 15 was used.

Fig. 3 An example of the experimental equipment working during field evaluation

To determine the magnitude of energy employed in the vertical tillage, a set of 14 different tests were carried out with different chisel plough arrangements. Eight replicates for each test were performed and for practical purpose the tests were divided into three blocks (I, II and III), as shown in **Table 1**.

In the block (I), treatments of a chisel plough were analyzed with and without wings, comparing them with the treatments of two individual frontals chisel at two depths, 0.20 and 0.30 m. In the block (II), treatments of three tines were analyzed; two leading ones to different depths of 0.20 and 0.30 m combined with a rear tine to 0.30 m depth (with or without wings). In the block (III), treatments were compared the performance of two rear tines with a spacing set to 1.20 m among them with the three different geometries of wings.

In each treatment the measured variables were: the total draft in kN, the soil disturbed area in m^2 and the specific soil resistance in kNm^{-2}. To determine the disturbed soil cross section, a profile meter with a graduated ruler was used to measure the depth for each 0.10 m of the working width.

Results and Discussion

The **Fig. 3** shows the apparatus employed under field conditions, at "rancho Navidad" at Coahuila State of Mexico.

In **Table 2** it can be observed that with the use of a single tine plough without wings, the specific soil resistance is significantly higher by 121.1 kNm^{-2} in comparison with the

Table 2 Test results of the first block of experiments (I)

Chisel tine position	Wing's Size, m	Chisel tines draft force, kN		Soil disturbance area, m^2		Proportion, %	Specific soil resistance, kN/m^2		Proportion, %
(1)Rear chisel tine	*	14.9	b	0.126	d	54.5	121.1	a	100.0
Winged chisel tine	0.30 (ACH)	11.8	d	0.139	c d	60.2	86.6	b	75.6
Winged chisel tine	0.45 (AM)	12.7	c d	0.158	b c	68.4	81.7	b	67.5
Winged chisel tine	0.60 (AG)	13.6	c	0.171	b	74.0	82.4	b	68.0
Two shallow tine to 0.20 m deep	*	13.5	c	0.157	b c	67.9	86.9	b	71.8
Two shallow tine to 0.30 m deep	*	18.371	a	0.231	a	100.0	80.1	b	66.1

***** Chisel tines without wings. **Note:** The rear chisel tine remains at constant depth of 0.30 m. **†** Treatments not followed by the same letter are significantly different at a confidence level equivalent to 95 %.

Table 3 Test results of the second block (II) of tests

Shallow tines position		Width size of wings, m	Total draft force, kN		Soil disturbed cross section, m^2		Proportion, %	Specific soil resistance, kN/m^2		Proportion, %
Spacing, m	Depth, m									
0.60	0.20	0.30	20.073	c	0.269	b	82	75.174	b c	89
0.60	0.20	0.45	21.03	b c	0.286	b	87	73.430	b c	87
0.60	0.20	0.60	22.204	a b	0.276	b	84	80.501	a b	95
0.60	0.20	*	17.422	d	0.208	c	64	84.341	a	100
0.60	0.30	*	23.129	a	0.327	a	100	70.772	c	84

* Wingless Chisel tines † Treatments not followed by the same letter are significantly different at a confidence level equivalent to 95 %.

resistance for a chisel tine with any geometry of wings, which had a mean value of 83.5 kNm^{-2}. The highest demand of draft was obtained by the increase of working depth combined with the use of different wing's widths; however, this created a larger soil disturbance area resulting in a reduction of the specific soil resistance.

A considerably reduction of specific soil resistance was obtained with the use of wings attached to a chisel tine tip compared with the use of a wingless chisel tine working both tines at a depth of 0.30 m. Similar results on the reduction of the specific soil resistance were obtained by Spoor and Godwin (1978), when compared the use of a chisel tine with two different geometries of wings (0.30 and 0.42 m respectively) with a conventional subsoiler working at the same depth, and also founded no significant difference in this parameter with the use of the two wing widths.

Fig. 4 shows the effect on disturbed soil area with different experimental arrangements. The best performance was obtained with two leading chisels tines working to a 0.30 m depth with a 0.231 m^{-2} followed by single tine with different wing sizes and then by a single chisel without wings. Similar results were found by Camacho and Magalhaes (2004) where it was shown that the effect of the use of winged subsoiler, compared to traditional chisel plough, for vertical tillage in the increment of soil disturbed area and the reduction of the specific soil resistance.

Table 3 shows the results when the apparatus was set with three tines with different arrangements. The highest draft demand was produced with three chisel tines without wing working at 0.30 m depth followed by the arrangement of two front shallow tines at 0.20m and a rear chisel tine with wings at 0.30 m depth. As well as the specific soil resistance does not show significant difference regarding the increment of size of wings with a mean of specific soil resistance of 76 kNm^{-2}.

Also in **Table 3** are shown the results when the two leading chisels tines working at 0.20 m and a rear chisel tine with 0.45 width size wings to a depth 0.30 m compared with the two frontal chisels at 0.20 m and a rear chisel at 0.30 m without wings, showing a significant difference in the specific soil resistance from 73 to 84 kNm^{-2} respectively, which represents a reduction of 13 % between treatments. Di Prinzio *et al.*, (2001), found similar results with a significant difference of 17.4 % in the specific soil resistance when compared the use of a subsoiler with and without wings.

Fig. 5 shows a comparison of cross section areas of the five tests carried out in the block of experiments (II), where the test four with the arrangement of two leading rigid tines at a depth of 0.20 m and a rear chisel at 0.30 m with 0.45m wings, shows the better performance in term of specific soil resistance.

In **Table 4** shows the test results carried out with two rigid tines working to a depth of 0.30 m and

Fig. 4 Soil disturbed area with five different treatments

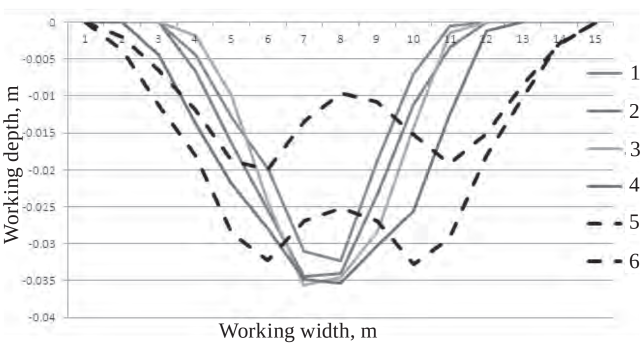

Fig. 5 Soil disturbance comparisons with second block test

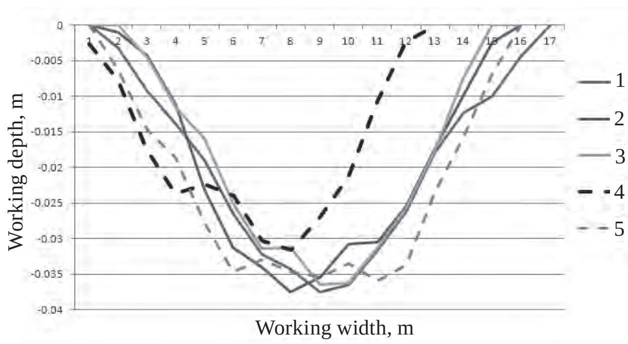

Table 4 Test results of the third block (III) showing specific soil resistance with different winged tine geometries

Rear chisel tine position		Width size of wings, m	Total force, kN		Soil disturbance, m^2		Proportion, %	Specific soil resistance, kN/m^2		Proportion, %
Spacing, m	Depth, m									
1.20	0.30	0.30	30.007	c	0.315	b	73	95.5	a	100
1.20	0.30	0.45	31.5	b	0.331	b	76	95.7	a	100
1.20	0.30	0.60	34.9	a	0.434	a	100	80.67	b	84

† Treatments not followed by the same letter are significantly different at a confidence level equivalent to 95 %.

spacing of 1.20 m, observing that the demanded draft are statistically different for the three evaluated wing sizes. In relation to the soil disturbance, there was no statistically difference when using 0.30 m and 0.45m wings; however, there was a difference in the specific soil resistance from 81 to 95 kNm^{-2} between tines with different wing sizes.

Conclusions

The arrangement of a single chisel with three different sizes of wings, working at 0.30m depth against two front chisels to 0.20 m did not show significant differences in the specific soil resistance with a mean value of 83 kNm^{-2}. A reduction of 30 % in the soil specific resistance was obtained with the use of any winged chisel in comparison with a traditional chisel tine working with all the arrangements at a 0.30 m depth.

On the second block of tests, the arrangement with two front chisels working at 0.20 m depth together with a rear chisel with 0.45 m wings at 0.30 m, the results showed a reduction of specific soil resistance of 13 %, in comparison with the use of two leading chisels at 0.20 m depth and a rear chisel without wings at 0.30m.

On the third block of tests with two chisels with wings of 1.20 m of spacing resulted in significant reduction of the specific soil resistance with the use of 0.60m wing in comparison with the other wings with values from 84 and 100 kNm^{-2} respectively.

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Spatial Farm Power Usage Patterns in the State of Haryana, India

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Abstract

Haryana, a major agriculturally developed state in India, was taken up for a detailed study on its mechanization status. The present status of farm power availability in 21 districts of the state (4 agro-climatic regions) was evaluated in terms of tractive and stationary power, and their relationships with food grains productivity.

Farm tractive power grew from 0.036 kW.ha^{-1} in 1967 to 1.78 kW.ha^{-1} in 2009, the growth rate remaining synonymous with the food grains productivity growth from 736 kg.ha^{-1} to 3,500 kg.ha^{-1}. Although the western zone had lowest tractive power (1.75 kW.ha^{-1}), it's tractive productivity was highest (2,107 kg.kW^{-1}), and lowest (1,251 kg.kW^{-1}) in southern region with tractive power of 2.75 kW.ha^{-1}. The northern and central zone had tractive productivity close to 1,500 kg.kW^{-1}. Among the districts in western region, Fathebad and Sirsa had highest tractive power and also highest productivity, while Bhiwani had lowest tractive power and lowest productivity. Tractive power availability was inversely related to land holding size.

The average stationary power use in the state was 0.89 kW.ha^{-1}, ranging between 0.44 and 1.42 kW.ha^{-1}. The southern zone with 94.5 % of net irrigated area under tubewell invested 34.5 % of total mechanical power for irrigation, while the western zone with 27.75 % under tubewell irrigation invested 24.7 % of total mechanical power for irrigation. Districts as Mahendragarh, Kaithal, Karnal, Panipat, Rewari, Sonipat use high stationary power. On the other hand, Bhiwani, Hissar and Mewat had low level of stationary power use. Some of the districts as Kaithal, Karnal, Panipat, Sonipat appeared to use excess stationary power than required.

For assessing comprehensive impact of mechanical power uses, a Mechanization Index (ratio of tractive power and mechanical power) was employed. The Index fitted well with the trends of food grains productivity, fertilizer consumption rate and percent food grains gross irrigated area. Mechanization Index was highest (0.75) in the western zone and lowest (0.65) in the southern zone. It reflected that appropriate mechanization is closely related to food grains productivity.

Introduction

Availability of adequate farm power is very crucial for timely farm operations for increasing production and productivity and handling the crop produce to reduce losses. Farm mechanization inputs particularly tractor power has helped India in increasing the food grain production many folds to meet the country's food requirements. The structure of energy consumption in Indian agriculture has changed a marked shift from animal and human power to tractors, electricity and diesel power. The consumption pattern of both direct and indirect energy inputs has revealed that the energy consumption per hectare of net as well as gross cropped area has increased (Jha *et al.,* 2012). Tractorisation, as backbone of farm mechanization, has played a pivotal role in bringing green revolution in the country. During the last four decades, the average farm power availability in India increased from 0.40 kW/ha in 1971-72 to about 1.46 kW/ha in 2004-05. As the usage of tractors in Indian agriculture accelerated, the net power from tractors and draught animals reached at a level of 73.39 and 21.5 million kW in 2004-05 (Vishal and Gupta, 2009).

Agriculture is the most important sector of the economy of Haryana State. Availability of adequate farm power to achieve timeliness of operations is a critical factor for achieving higher productivity and yields. There has been a continuous increase in the population densities (No.11,000 ha) of tractors, diesel engines and electric motors. The tractor population increased from 3.45 tractors/1000 ha in 1970-71 to 59.45 tractors/1000 ha in 2000-01 (Kumar *et al.,* 2004).

Haryana State established in November 1, 1966, lies between 270º 37´ to 300º 35´ latitude and 740º 28´ to 770º 36´ longitude at an altitude ranging from 213.36 to 1,097 m. The state is administratively divided into 4 Divisions, 21 districts, 75 Tehsils and 119 Blocks. The rural population is about 71 % of the total population residing in 6,781 (out of 6,955) villages. It has a total geographical area of 4.42 Mha, of which 3.576 Mha is net seeded area. The average cropping intensity of the state is 1.82 with major crops of paddy, wheat, barley, maize, sugarcane, groundnut, rapeseed and mustard, cotton, etc. The total food grains production during 2009-10 was 15.36 Mt cultivated in 4.54 Mha. There are two agro-climatic zones in the state. The north western part of the state is suitable for the cultivation of paddy, wheat, vegetable and temperate fruits and the south-western part is suitable for high quality agricultural produce, tropical fruits, exotic vegetables and herbal and medicinal plants. The agro-climatic zones are further subdivided in the State as following:

1. Northern Ambala, Karnal, Kurukshetra, Panchkula, Panipat, Yamunanagar
2. Central Jhajjar, Jind, Kaithal, Rohtak, Sonipat
3. Western Bhiwani, Hisar, Fatehabad, Sirsa
4. Southern Faridabad, Gurgaon, Mahendragarh, Mewat, Palwal, Rewari

The average rainfall in the state is 455 mm. About 44 % of irrigation water in the state is provided by the canals. The various canals operating in the state include Western Yamuna Canal, Gurgaon Canal, Jui Canal, Jawaharlal Lal Nehru Canal and Bhakra Canal. The rest of 56 % of irrigation water is provided by wells/ tubewells. The net irrigated area in the state was 28.77 thousand ha in 2008-09, while the gross irrigated area was 55.44 thousand ha.

The study was undertaken to assess the spatial farm power usage patterns in the state, examine the variations within agro-climatic regions, and their relationships with food grains productivity.

Materials and Methods

Time series data on all aspects of farm mechanization in Haryana are not readily available from one source. For the present study, secondary yearly data published by the Department of Economic and Statistical Analysis, Government of Haryana (Anon, 2008; Anon 2010b, Anon, 2011a,b) ; Planning Department, Government of Haryana; Department of Agriculture, Govt. of Haryana; Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India (Anon, 2010c); Central Groundwater Board, Govt. of India (Anon, 2007a-p); International Energy Initiative (Anon, 2010a), World Bank (Anon 2001a,b), and allied Departments were used. Field surveys were conducted in some districts of Haryana, and primary data collected therein were also used.

Results and Discussion

During the period 1967 to 2009, the area under food grains increased from 3,520 to 4,621 thousand ha at a slow annual compound growth rate of 0.65 percent. Food grains production, on the other hand, increased from 2,592 to 16,178 thousand tonnes during the period at an annual compound growth rate of 4.45 percent. The food grains productivity thus showed annual compound growth rate of 3.78 percent (**Table 1**). It could be this seen that food grains production increased at a much higher rate than that of area under crop, contributing to 3.78 % growth rate of productivity.

Farm tractor population in the state grew from 4,803 in 1967 to 264,973 units in 2009 at an annual compound growth rate of 10.02 percent. The weighted average tractor power in the state simultaneously increased with tractor population from 26.1 kW to 30.96 kW. As a consequence, the unit power availability increased from 0.036 kW.ha^{-1} to 1.775 kW.ha^{-1} (**Table 1**) at an annual compound growth rate of 9.75 percent. Tractive power growth had thus been at a higher rate than food grains productivity.

The patterns of tractive power

Table 1 Trends of food grains production and tractor population in Haryana

Year	Food grains			Tractor
	Area, ‘000 ha	Production, ‘000 t	Yield, kg.ha^{-1}	Power, kW.ha^{-1}
1967	3,520.0	2,592.0	736.36	0.036
1971	3,867.7	4,771.0	1,233.55	0.083
1976	4,211.2	5,040.0	1,196.81	0.158
1981	3,962.5	6,035.5	1,523.15	0.347
1986	4,043.2	8,146.6	2,014.89	0.537
1991	4,079.3	9,558.7	2,343.22	0.833
1996	4,020.5	10,171.7	2,529.96	1.052
2001	4,343.5	13,294.8	3,060.85	1.384
2006	4,311.4	13,005.8	3,016.61	1.687
2008	4,477.2	15,294.1	3,416.00	1.812
2009	4,621.0	16,177.8	3,500.93	1.775

availability and crop productivity over the years 1967 to 2009 is shown in **Fig. 1**. It would be seen that farm power exponentially increased from 0.036 $kW.ha^{-1}$ to 0.347 $kW.ha^{-1}$ between 1967 and 1981, and then linearly increased to 1.69 $kW.ha^{-1}$ in 2006. From 2006, the growth slowed down to reach 1.81 $kW.ha^{-1}$ in 2008 and to 1.78 $kW.ha^{-1}$ in 2009. This was due to reduction in sale of tractors of 41-50 HP from 35.4 % to 34.38 % and more than 50 HP from 20.96 to 19.34 % in 2009 as compared to that in 2008.

Crop productivity, on the other hand, showed an increasing trend during the period. The growth rate, however, slightly slowed down since 2001 from 3,060.85 kg/ha and reached to 3,500.93 kg/ha in 2009.

The trend of tractive power availability and crop productivity over the period 1967-2009 is shown in **Fig. 2**. It could be observed that tractive power grew from 0.036 $kW.ha^{-1}$ in 1967 to 1.78 kW/ha in 2009, the growth rate remaining synonymous with the food grains productivity growth from 736 kg/ha to 3,500 kg/ha. Tractive power availability and crop productivity followed a second degree polynomial relationship as given below with R^2 of 0.977.

$$y = -394.1x^2 + 2085.x + 875.5 \quad (1)$$

Where,

X = Tractive power, $kW.ha^{-1}$, and

Y = Crop yield, kg/ha.

Tractive Productivity in Agro-Climatic Zones

The tractive power availability during 2009 varied between the agro-climatic zones (**Fig. 3**) of the State. The western zone had least tractive power of 1.75 $kW.ha^{-1}$, followed by central zone (2.29 $kW.ha^{-1}$). The northern and southern zone tractive power availability varied in a narrow range of 2.49 and 2.55 $kW.ha^{-1}$.

From **Fig. 3**, it could be also observed that the regions with higher land holding size had lower tractive

Fig. 1 Patterns of tractive power and crop productivity growths in Haryana

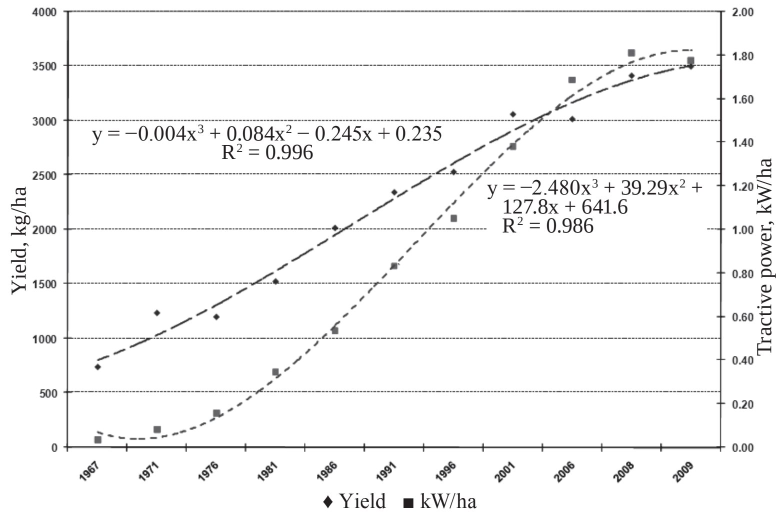


Fig. 2 Trend of tractive power and crop productivity in Haryana during 1967 and 2009

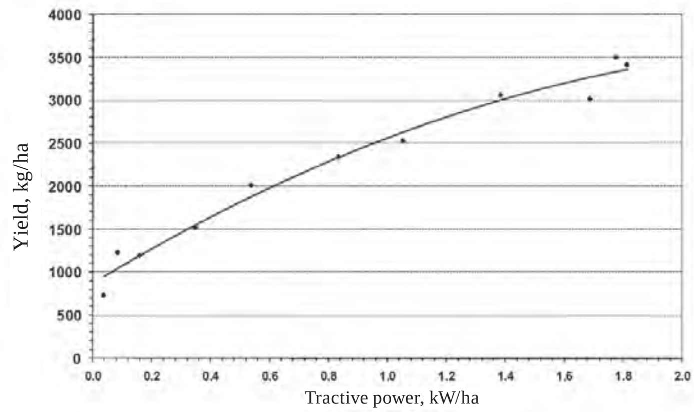


Fig. 3 Tractive power availability and land holding size in agro-climatic zones of Haryana

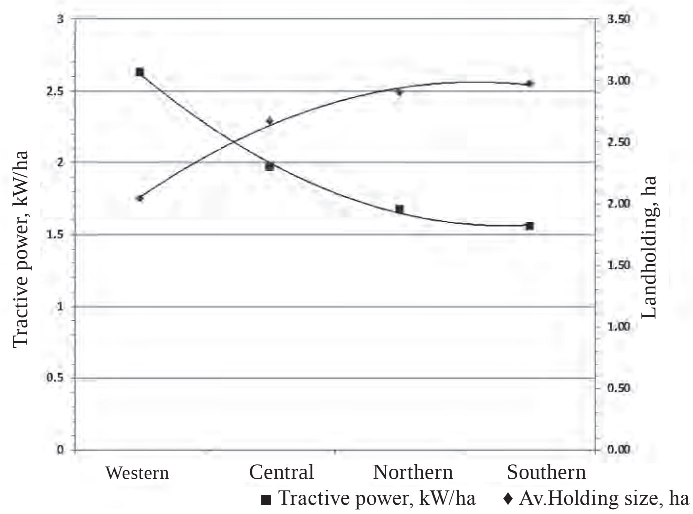


Fig. 4 Trend of agro-climatic zone wise tractive power and crop productivity in Haryana

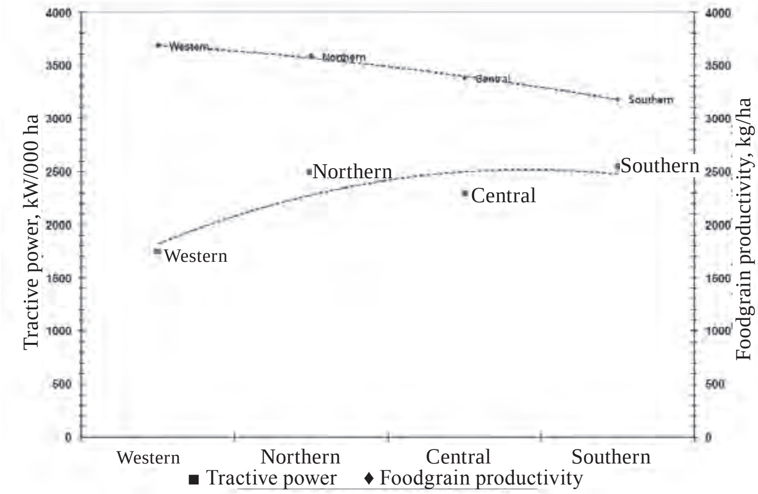


Fig. 5 Trend of tractive power productivity and land holding size productivity in agro-climatic zones of Haryana

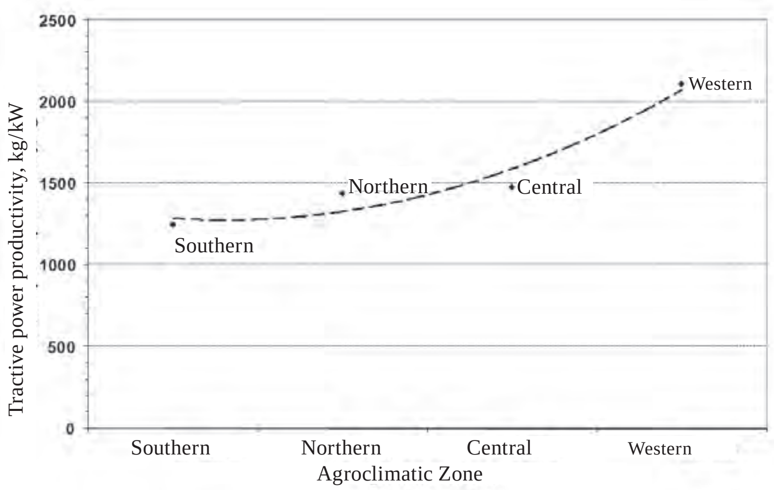
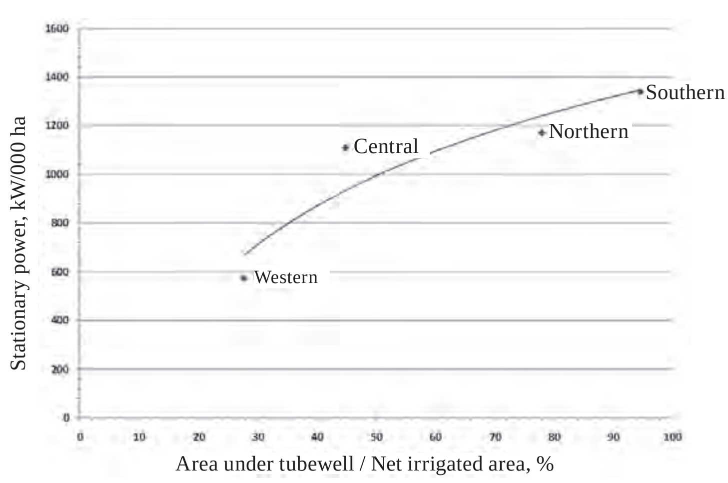


Fig. 6 Relationship between stationary power availability and area under tube well command in agro-climatic zones of Haryana



power, and vice versa. The average holding size of western zone was 3.07 ha with tractive power of 1.75 $kW.ha^{-1}$. In contrast, the average holding size of southern zone was 1.82 ha with tractive power of 2.55 $kW.ha^{-1}$. The impact of individual ownership of tractors, with lower holding size zone having higher tractive power due to higher tractor population, was thus clearly reflected.

The patterns of zone-wise tractive power availability and crop productivity are shown in **Fig. 4**. Food grains productivity was highest in western zone (3,688 kg/ha), sequentially followed by northern (3,587 kg/ha), central (2,289 kg/ha) and southern (2,546 kg/ha) zones. The western zone had least tractive power of 1.75 $kW.ha^{-1}$, followed by central zone (2.29 $kW.ha^{-1}$). The northern and southern zone tractive power availability varied in a narrow range of 2.49 and 2.55 $kW.ha^{-1}$.

The tractive productivity had an inverse relationship with land holding size in the agro-climatic zones, **Fig. 5**, and followed second degree polynomial form as given below with R^2 of 0.933.

$y = 110.0x^2 - 289.6x + 1467$ .....(2)

Where,

y = Tractive productivity, $kg.kW^{-1}$, and

x = Land holding size, ha.

Although the western zone had lowest tractive power (1.75 $kW.ha^{-1}$), its tractive productivity was highest (2,107 $kg.kW^{-1}$). Tractive productivity was lowest (1,251 $kg.kW^{-1}$) in southern region with tractive power of 2.75 $kW.ha^{-1}$. The northern and central zone had tractive productivity close to 1,500 $kg.kW^{-1}$. The trend reflected that higher holding size led to lower investment in tractor power as also higher land productivity, a feature indicating better impact of mechanization.

Among the districts in western region, Fathebad and Sirsa had highest tractive power and also highest productivity, while Bhiwani had lowest tractive power and lowest productivity, **Table 2**.

Stationary Power

The major use of stationary power in the state is for lift irrigation. The average stationary power use in the state was 0.89 kW.ha^{-1}, ranging between 0.44 and 1.42 kW.ha^{-1}. Among the agro-climatic zones, western zone had 27.75 % of net irrigated area under tube well command, while the central, northern and southern zone had 44.89 %, 78.02 %, 94.65 %, respectively. The stationary power availability in the western, central, northern and southern zones was 0.57, 1.11, 1.17 and 1.34 kW.ha^{-1}, respectively. Stationary power use thus had an increasing trend with increased area under tube well command, and had a logarithmic relationship (**Fig. 6**) with percent area under tube well ($R^2 = 0.87$) as following:

$y = 553.8 \ln(x) - 1173$ ....(3)

Where,

y = Stationary power, kW.ha^{-1}, and

x = Area under tube well irrigation/ Net irrigated area, percent.

As seen from **Fig. 7**, districts as Mahendragarh, Kaithal, Karnal, Panipat, Rewari, Sonipat used higher stationary power. On the other hand, Bhiwani, Hissar and Mewat had low level of stationary power use. Some of the districts as Kaithal, Karnal, Panipat, Sonipat appeared to use excess stationary power than required.

Mechanization Index

Mechanization of crop production systems is viewed as a package of technology to (1) ensure timely

Table 2 Tractive power and crop productivity in districts of Western Agro-climatic Zone of Haryana (2009)

District	Tractive power, kW.ha^{-1}	Crop productivity, kg.ha^{-1}
Bhiwani	1.60	2,255.60
Hisar	1.74	3,763.68
Fatehabad	2.08	4,777.62
Sirsa	1.69	4,544.18

Fig. 7 Trend of stationary power availability and tube well command area in districts of Haryana

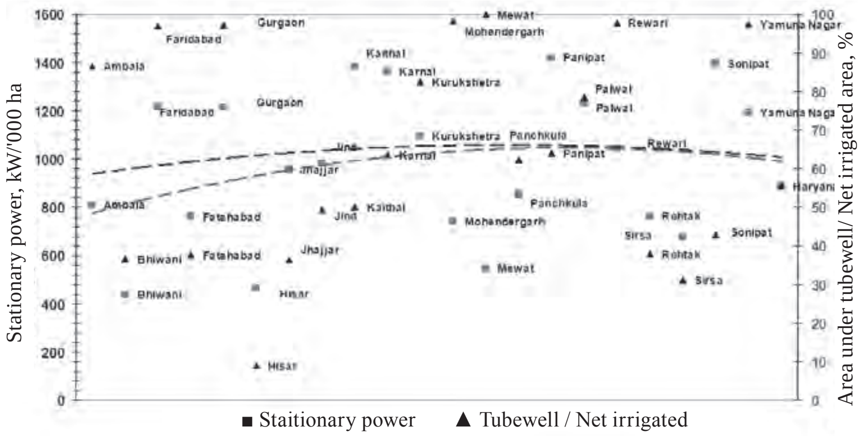


Fig. 8 Trend of mechanization index in agro-climatic zones of Haryana

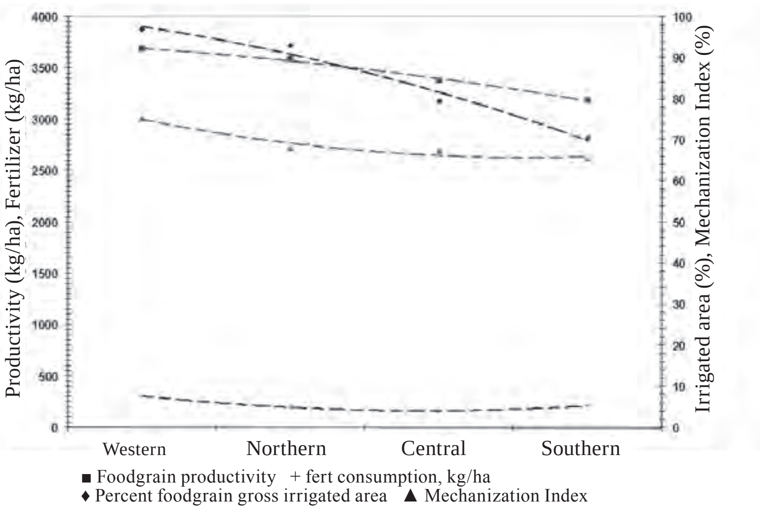
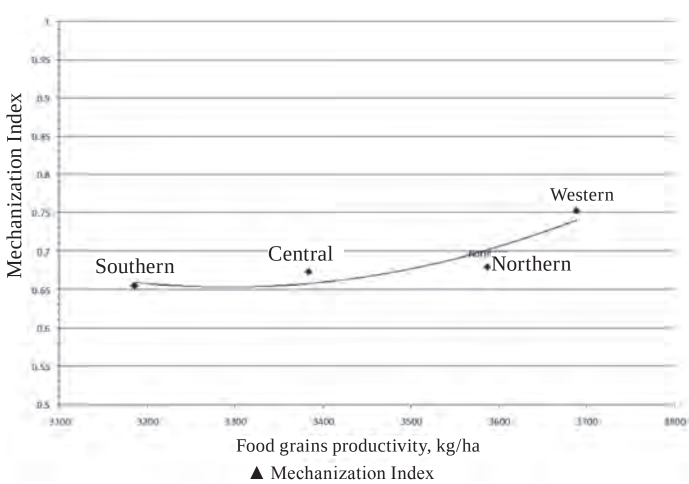


Fig. 9 Trend of mechanization index and food grains productivity in agro-climatic zones of Haryana



completion of field operations to increase land productivity through effective utilization of inputs, reduce production losses, and improved quality of produce, (2) increase labour productivity using labour-saving and drudgery-reducing devices, and (3) on some occasions, decrease production cost by offsetting increased costs of draught animal or labour. Mechanization is, therefore, location-specific as well as dynamic with the techno-socio-economic status of an area.

Quantification of degree of mechanization is a complex issue due to the influence of many technical, social and economic factors that govern its level of acceptance. It is, therefore, difficult to be directly quantified. Various methods have been used by researchers to relate these factors. Majority of methods has relied heavily on translation of relevant factors into economic terms for purpose of comparison. Such exercises demand detailed data, and involve complex mathematical algorithms. Simpler methods are often required for quick assessments and with relatively small information bases (Singh and De, 1999).

Mechanization indicator has also been expressed as a ratio of mechanical power over total farm power. Mechanical power supports a higher level of technology (like land reclamation, deep plowing, precision planting, high lift/high discharge water lifting, harvesting, threshing, combine harvesting, etc.) which are essential inputs for intensive agriculture with reduced drudgery, and reflect higher stages of mechanization. Thus the ratio of mechanical power input to total power input, as mechanization index factor, is another indicator of the level of mechanization.

Such indicator, however, considers mechanical power as an entity without assigning weight to the quality of its contribution to the objectives. Consideration of mechanical power as a whole does not segregate the role of stationary power and tractive power, the role of the two components being different in terms of technology adoption. As an example, adoption of mechanization in India for crucial stationary operations is evident from the fact that in 1996, out of the farm power derived from mechanical power sources, 64 % was used for irrigation and threshing. (Singh and De, 1999) Tractive power is utilized for higher levels of technology for intensive agriculture with reduced drudgery to perform complex operations (as precision land preparation, seeding and harvesting) within time constraints and with comfort and dignity to the operators, and therefore achieves higher goals.

Singh and De (1999) suggested that an energy value based mechanization indicator with tractive power as reference parameter can be used for comparison of the various stages of mechanization. However, sufficient and reliable data on use patterns of farm mechanical power in the catchment area is required for such assessment.

For assessing a simple and comprehensive footprint of technology-use based mechanical power availability, a Mechanization Index (ratio of tractive power and total mechanical power) was employed.

The Index fitted well with the trends of food grains productivity, fertilizer consumption rate and percent food grains gross irrigated area shown in **Fig. 8**. Mechanization Index was highest (0.75) in the western zone, and least (0.65) in the southern zone.

Regression model of the Mechanization Index with food grains productivity (**Fig. 9**) followed a second degree polynomial form represented ($R^2 = 0.837$) as:

$$y = 6E - 07x^2 - 0.003x + 6.648 \qquad (4)$$

Where,

y = Mechanization Index, and

x = Food grains productivity, kg.ha^{-1}.

It reflected that appropriate mechanization is closely linked to food grains productivity. The scenario indicated that mechanization footprint in the state has reached higher levels of technology for complex farm operations.

Conclusions

1. Unit tractive power availability in Haryana increased from 0.036 kW.ha^{-1} to 1.775 kW.ha^{-1} at an annual compound growth rate of 9.75 percent. Tractive power growth was at a higher rate than food grains productivity growth rate of 3.78 percent. Tractive power availability and crop productivity followed a second degree polynomial relationship.

2. Tractive power availability during 2009 varied between the agro-climatic zones of the State, and ranged between 1.75 and 2.55 kW.ha^{-1}. Regions with higher land holding size had lower tractive power, and vice versa.

3. Tractive productivity among the zones varied between 1251 and 2107 kg.kW^{-1}, and had an inverse second degree polynomial relationship with land holding size. Higher holding size led to lower investment in tractor power as also higher land productivity, a feature reflecting better impact of mechanization.

4. Average stationary power use in the state was 0.89 kW.ha^{-1}, ranging between 0.44 and 1.42 kW.ha^{-1}. Stationary power use showed an increasing trend with increased area under tube well command, and had a logarithmic relationship with percent area under tubewell. Some districts appeared to use excess stationary power than required.

5. A Mechanization Index (ratio of tractive power and total mechanical power) was employed to assess the technology-use based footprint of mechanical power. The

Index fitted well with the trends of food grains productivity, fertilizer consumption rate and percent food grains gross irrigated area. Mechanization Index was highest (0.75) in the western zone, and least (0.65) in the southern zone. Mechanization footprint in the state exhibited higher levels of technology for complex farm operations.

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Techno-Economic Appraisal for Strategic Planning of Rice Mechanization in Kerala, India

by

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Abstract

Techno-economic analysis of farm machinery in relation to the specific agro-climatic scenario provides vital information required for planning and implementing a mechanization strategy in Kerala. Information on economics and technical data of machinery were acquired from studies taken up in the central zone of Kerala state, India. The highly vulnerable position of rice production systems under low level of mechanization as well as the economic superiority of high level mechanization over low level mechanization was revealed in the comparative evaluation. The plotted curves depicting the variation of hourly operation costs (HOC) and unit area operation costs (UAOC) of different machines with respect to annual working hours (AWH) as well as annual area operated can serve as a guideline in decision making for the use of machinery. The command area of the individual machines and their break even points with respect to AWH and annual area operated were estimated.

Rice being the staple food of the people of Kerala state in India, sustaining its cultivation is vital for assuring food security in the State. Over the last three decades, area under rice cultivation has drastically reduced to reach a mere 2,34,013 ha. The annual rice production in Kerala during 2009-10 was only 598,339 tonnes as against the actual requirement of 3,800,000 tonnes. Apart from assuring food security, sustaining paddy fields is also essential for maintenance of ecological balance. Once the rice fields are altered for other crops necessitating fast drainage of rain water, these can no longer serve as ground water recharge zones and the consequential lowering of ground water level results in drinking water shortage. Hence it is imperative to sustain rice cultivation in Kerala for ensuring food security, for assuring ground water and for preservation of biodiversity.

The deceleration in the urge to take up rice cultivation is due to the fact that highly labour intensive cultivation practices are not economically sustainable in a state where high wage rates are rampant. Nevertheless, in the periods of intense crop production activity farmers face acute labour shortage. The universal solution to these problems was adoption of mechanized farming, but the pace with which mechanization advanced in the wheat belt of India could not be noticed in Kerala (James, 1989). James and Regina (1993) reported that unlike other agricultural technologies, agricultural mechanization has severe limitations in farm level adoption. James and Ahmed (1994) delineated a strategy for technology transfer in this sector. James *et al.* (1995) reported that the fear of labour displacement due to agricultural mechanization was baseless and rice farm mechanization offers employment opportunities in the operation, service, manufacture and marketing of machines, which the educated youth of this highly literate state will find more attractive. It has been reported that the cost of cultivation of rice in Kerala can tremendously be reduced by selective mechanization, as the wage rates in Kerala were the highest in India (James *et al.,* 1996). Mechanization of highly labour intensive operations like transplanting and harvesting offers a helping hand to the farmer (James and Pillay, 1998).

The important questions in relation to farm mechanization are what type of mechanization is required and, when and how should technology be applied at the farm level (Rijk, 1986). Economic analysis of farm machinery in relation to the specific agro-climatic and socio-economic scenario provides vital information required for planning and implementing a mechanization strategy (James *et al.,* 2006). Even though a set of machinery for rice cultivation has been proposed by James (2008), a detailed techno-economic analysis was lacking. Wiren-Lehr (2001) emphasized that the objective of concepts to implement sustainability in agriculture is to consolidate the complex and diverse principles of the theoretical paradigm and to transform them into recommendations for agricultural practices. With rice machinery acquiring popularity, farmers and field officers are often unable to adopt appropriate machinery suited to specific conditions of padasekharams (agglomerated paddy fields of varying areal extends and individual fields within a specific padasekharam have identical agro-ecologic and similar geophysical situations). It is a handicap that a strategic guideline is lacking in promulgating an appropriate rice mechanization strategy vis-a-vis the specific situations and hence an analysis of the techno-economic aspects of rice machinery adoption for the central zone of Kerala was attempted.

Methodology

Even though there are different rice cultivation systems in Kerala, the study was restricted to the predominant 'transplanted system' for which mechanization is highly sought. In the traditional system, the practice is to sow seeds in a nursery allowing the seedlings to grow for about a month, then uprooted and transplanted manually in the main field.

Preliminary Study

A preliminary investigation was taken up during 2008-10 in Thrissur and Palakkad districts so as to analyze the comparative economics of Low Level Mechanization (LLM) and High Level Mechanization (HLM) in transplanted rice. The costs of operations including material cost and labour cost were obtained from the farmers in both systems of cultivation and were summed up to obtain the Total Cost of Cultivation (TC). The income was worked out considering that the price of raw paddy as Rs. 15/- per kg and the cost benefit ratio calculated.

The system under LLM used tractors for land preparation and manual sprayers for application of plant protection agents. Transplanting, weeding, harvesting and threshing were carried out manually. The HLM system used tranplanters, power sprayers and combine harvesters in addition to the improved KAU puddler for puddling as proposed by James (2008). It was considered that all the machines were used under custom hiring. It was considered that fertilizers were applied as per the KAU recommendation (KAU, 2009). Custom hire charges for machinery and input costs (seeds, fertilizers and plant protection chemicals) prevalent as on 1st July 2011 in the study area were considered. Wage rates were Rs. 350/-and Rs. 250/- per day for men and women labourers, respectively.

Mechanization in Different Operations

The primary operation in rice cultivation is land preparation. Land preparation in wet lands (puddling) in most of the rice fields in Kerala are done with tractors. This operation is generally done with 35-45 horse power tractors attached with special steel wheels called 'cage wheels'. Generally 7 to 10 hours of cage wheel puddling with tractor is required per ha of rice field. At the same time, about 40 % time saving in puddling was possible by attaching the 'KAU helical blade puddler' to tractors in systems under HLM.

Another operation done manually with spades is the repair of field bunds so as to have better water management in the paddy field. Maintenance of 5 cm water level in the field after transplanting is imperative for weed management. This is being done manually in both systems.

In manual transplanting of LLM system, seeds at the rate of 80-100 kg/ha (of main land) are either dry sown or wet sown (depending on field condition) for preparing the nursery. 25-30 day old seedlings are uprooted, tied into bundles, their roots washed and trimmed, carried to the main field and transplanted. They are transplanted by women labourers and men help in transporting the seedlings.

The Chinese 8 row self-propelled rice transplanter capable of transplanting seedlings at the row spacing of 23.8 cm. was first tested in Kerala at Regional Agricultural Research Station, Pattambi during 1995-96 where in the yield was reported to be on par with traditional transplanting (Anon., 1997). For transplanting with machine under HLM, a special type of nursery called 'mat nursery' is prepared for which the seed requirement is 50 kg/ha. At an age of 16-22 days, the nursery is ready for transplanting with the machine. These mats are cut into appropriate sizes suitable for the trays of the transplanter used. Three to six seedlings are planted in hills with a spacing of 14 or 17 cm.

In LLM system, manually operated 'knapsack sprayers' are generally used for spraying plant protection agents where as engine operated power sprayers were used in systems under HLM. The requirement of spraying can be different in different fields and seasons and is dependent on pest/disease out break. It was assumed in the present study that on an average one spraying was required.

Hand weeding was done by women in LLM and a manually operated push-pull type 'rotary weeder' was used in HLM. The weeder could save much labour in the machine planted fields.

Once the ripened crop was reaped

by women with sickles, tied into bundles, transported to the threshing yard and was threshed either by rubbing with feet or by beating against a stone or wooden pole in LLM system. The raw paddy was cleaned by winnowing and then dried. The harvesting and threshing operations in HLM are carried out with ‘Combine Harvesters’ capable of reaping and threshing simultaneously. The common track type rice combine (Claas make) was used.

Economic Analysis of Rice Machinery

The machines considered for detailed economic analysis were 35 hp tractor with KAU Puddler, 8 row riding type transplanter and combine harvester. There are situations warranting the use of reapers and threshers due to non-availability or non-accessibility of combines. Hence, walk behind type vertical conveyor reaper and flow through type thresher were also included for analysis. The data on field capacity, fuel consumption and labour requirement were gathered at the fields during operation under nearly ideal field conditions. The procedure for economic analysis of agricultural machinery suggested by Hunt (1977), and James *et al.* (2006) were adopted to evolve a strategic guideline in decision making as well as for promulgation of the most appropriate rice mechanization approach with respect to the specific situation.

The prevalent market prizes of the machines as on 1st July 2011 (C) were taken into account for working out the costs of operation of the machines. The annual fixed cost (AFC), which included interest on capital (10 % per annum), depreciation, insurance and taxes (1 % of C per annum), was calculated assuming that the life of machinery is 10 years and the junk value is 10 % of C. Hourly Fixed Cost, Rs./h (HFC) was obtained for different choices of Annual Working Hours (AWH), h/annum. AWH is dependent on Effective Annual Area (EAA), ha/year which is the sum of the areas operated in a year in all the seasons. Hourly Variable Cost (HVC) was calculated using the gathered data on fuel consumption, lubricant cost, operator’s wage rates, and repair and maintenance charges (0.005 % of C per hour of use). The Hourly Operation Costs, Rs./h (HOC) were estimated as the sum of HFC and HVC values for different AWH.

The field capacities of the machines (ha/h) were estimated from the field data. The probable Maximum Annual Working Hours (MAWH) for individual machines based on the agro-ecologic situation have been estimated by vis-à-vis analysis of the specific agro-climatic factors in the *padasekharams* which were considered representative of the central zone of Kerala. The corresponding HOC and Maximum Command Area, ha (MCA) were worked out. The Unit Area Operating Costs, Rs./ha (UAOC) with respect to the variation of AWH as well as EAA were analyzed. Break Even Hours (BEH) and Break Even Areas (BEA) for different machines, at which the UAOCs become equal to prevalent hire charges, have also been estimated.

Results and Discussion

The costs of cultivation under the two systems are illustrated in **Fig. 1**. Even though the cost of inputs and operation per ha is similar for items like repair of bunds and fertilizer application, there is considerable difference in the total cost of cultivation due to the differences in the cost for seeds as well as for the crucial operations ie., land preparation, transplanting, weeding, spraying and harvesting. The total cost of cultivation in HLM system (Rs.42,237.50 per ha) is only 70.5 % of that in LLM system (Rs.59,925/- per ha). In LLM system, the costliest operation is harvesting (19.8 % of TC) followed by transplanting (19.6 % of TC). In HLM system, the costs for these crucial operations were reduced to 57.9 % and 53.2 % respectively of that in LLM system. In HLM, the costliest operation is application of manures and fertilizers (27.3 % TC) followed by land preparation and harvesting (both 16.3 % TC). As significant differences in yield could not be observed between the two systems, the profit and cost benefit ratio has been worked out based on an average yield of 4,500 kg/ha prevalent in the zone among

Fig. 1 Comparative cost of operations (Rs/ha) in rice cultivation under different mechanisation levels

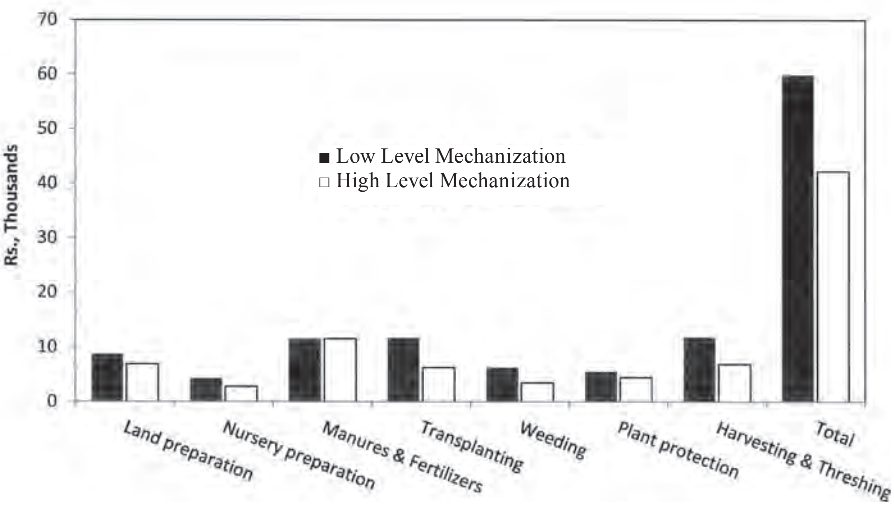


Table 1 Economic parameters of rice machinery

Machine	Capital, Rs. (thousand)	Annual Fixed Cost, Rs.	Hourly Variable Cost , Rs.	Field Capacity, ha/h	MAWH, h/annum	MCA, ha	HOC at MAWH, Rs/h	UAOC at MAWH, Rs./ha
35 hp Tractor with KAU puddler	445	94,500	305.3	0.15	800	120	423	2820
8 Row riding type transplanter	160	33,600	251.0	0.2	320	64	356	1780
Vertical Conveyor Reaper	70	14,700	278.0	0.3	320	96	324	1080
Flow Through Thresher	180	37,800	308.3	0.2	320	64	426	2130
Combine Harvester	2,200	462,000	650.8	0.33	800	264	1228	3721

progressive farmers. The profit in HLM was Rs.25,262.5/ha, where as it declined to a mere Rs.7,575/- in LLM. If the yield reduces below 4,120 kg/ha in LLM the enterprise will be in loss. This is a highly vulnerable situation in the wake of the threats of climate change. The resilience of the HLM system is quite evident from the threshold yield of 2,816 kg/ha. The cost benefit ratios were 1.6 and 1.13 for HLM and LLM systems, respectively. It is fairly evident that LLM system is no more economically sustainable without financial support from the government.

The major economic parameters of the machines are given in **Table 1**. For any agricultural machine, the cost of operation is inclusive of fixed costs like interest on capital, depreciation, taxes etc. which are chargeable on an annual basis irre-

Fig. 2 Cost of operation of tractor

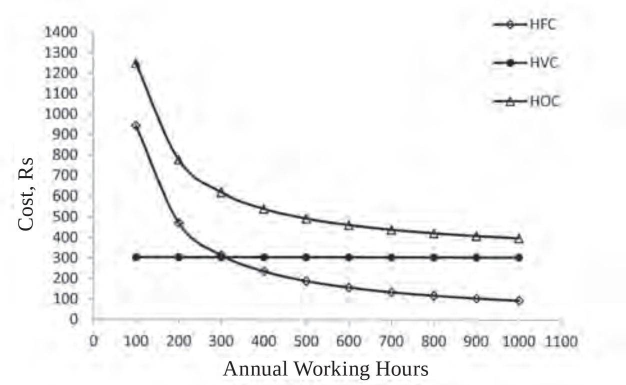


Fig. 3 Cost of operation of 8 row riding type transplanter

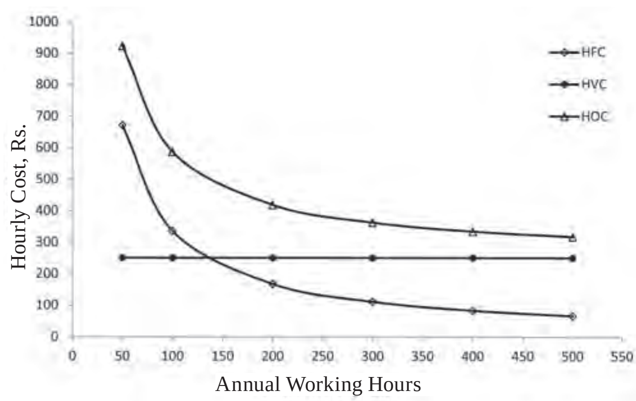


Fig. 4 Cost of operation of reaper

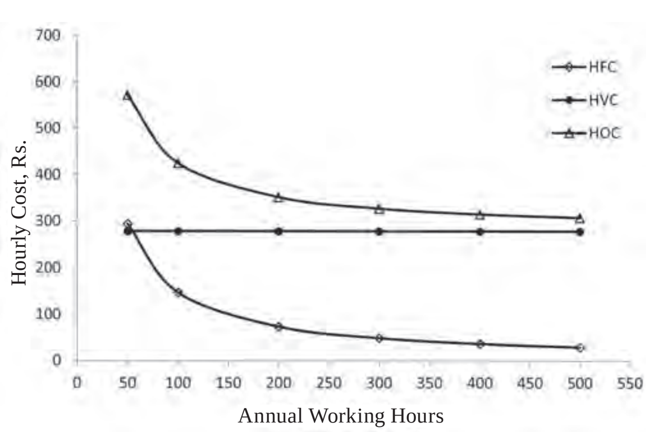


Fig. 5 Cost of operation of thresher

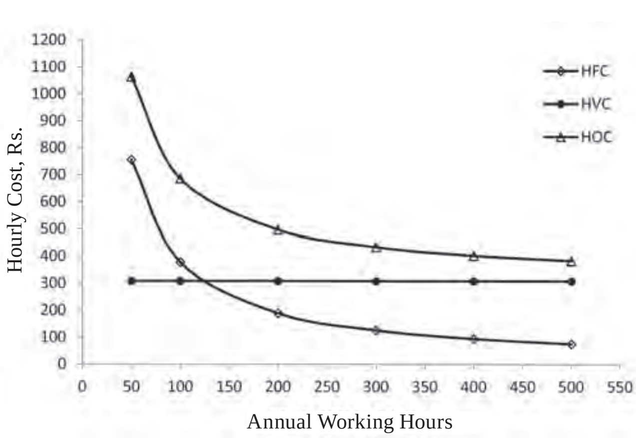


Table 2 Break Even Parameters of rice machinery

Machine	Hourly Custom Hire Charges, Rs./h	UAOC of Custom Hired Machines, Rs./ha	BEH, h	BEA, ha
35 hp Tractor with KAU puddler	500	3,333	485	73
8 Row riding type transplanter	1,000	5,000	45	9
Vertical Conveyor Reaper	500	7,143	66	20
Flow Through Thresher	1,000	5,500	55	11
Combine Harvester	2,000	1,667	342	113

*Includes wages of all the operators required

spective of the working hours. Variable costs such as fuel and lubricant cost, repair and maintenance cost and operator's wages are chargeable on hourly basis. The Annual Fixed Cost (AFC) is distributed over Annual Working Hours (AWH) and hence the Hourly Fixed cost (HFC) decreases with increase in AWH. In the case of the 5 machines considered, tractors and combine harvesters were assumed to work beyond the limitations of a specific padasekharam and hence the maximum possible working days were taken as 100 and 80 per annum, respectively. In consideration of the agro climatic situation in central zone, the other 3 machines had a maximum possibility for 40 days of work per annum. Daily working hours for machinery was taken as 8 hours except for combine harvester, which was observed to work for 10 hours daily. The corresponding MAWH and MCA for each of the machines are given in **Table 1**. It may be noted that MCA is the gross maximum area which can be covered by the machine in an entire year for all seasons taken together. The combine harvester had the maximum command (264 ha) followed by tractor (120 ha). In a double cropped area, the actual land area gets halved. In single cropped area, the days available for operation will be reduced from the estimated period. If a shrink in the period available for operation compared to the estimated maximum days occurs, there will be an obvious reduction in the command area. A safety factor of 10-15 days may also be applied in vulnerable agro-climatic situations, especially in the case of harvesting machines so as to face the threat of climatic adversities. The HOC and UAOC at MAWH (**Table 1**) show that all the machines can be operated at fairly lower costs, if there is a possibility to fully utilize the available time. The prospects of utilization beyond the boundaries considered can be explored in such cases.

The variations of HFC and HOC with respect to AWH for all the 5 machines are depicted in **Figs. 2** to **6**. The drastic increase in HOC with the reduction in AWH is obvious from the figures. The corresponding variations in UAOC for the different machines with respect to the area operated per annum are shown in **Fig. 7**. Either the area or the work-

Fig. 6 Cost of operatin of track type combine harvester

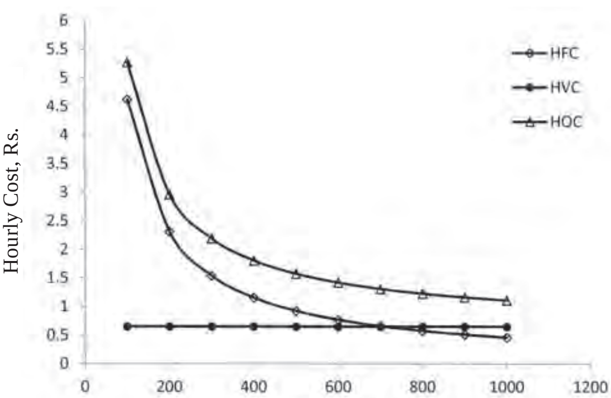
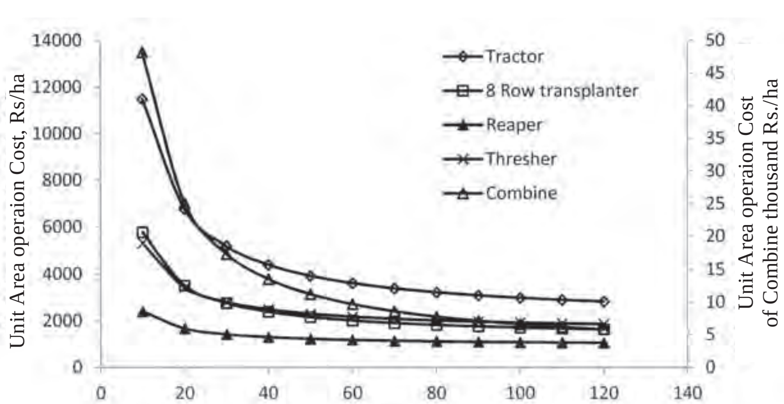


Fig. 7 Unit area operation cost at varying annual area operated



ing hours in specific situations can be superimposed to get a clear picture of the economics. The true cost of operation of these machines under the given situation can be readily assessed from these curves and hence can serve as a ready reference for decision making in the purchase of machinery.

The break even points determined with respect to the prevailing custom hire charges are shown in **Table 2**. At BEH, the HOC becomes equal to machinery hire charges and the corresponding area is given by BEA. The maximum BEH is for tractor followed by combine harvester and the minimum is for transplanter. The transplanter purchase becomes economical even if the gross operational area is only 9 hectares. But the purchase of combine will be economical only if the operational area is above 113 ha. And hence promotion of group mechanization strategy is advantageous to reap the full benefits of mechanization.

Conclusions

The economic superiority of high level mechanization over low level mechanization was spectacular in this analysis. The highly vulnerable position of systems under low level of mechanization does not permit any development of rice cultivation. At the same time, the inference that transplanted rice production system under high level of mechanization is economically attractive depicts a proactive sign for sustaining rice cultivation in Kerala. Thus, it was evident that mechanization is the prime factor for ensuring food security and preserving the wet lands in this ecologically fragile state of Kerala. But, it may not be economical to purchase machines, especially costly ones like combine harvesters, if there is no scope for using it for hours or area above the economic threshold levels determined by BEH and BEA. Group mechanization on padasekharam basis is the best choice for use of costly machines. It is recommended that the assessment of machinery requirement should be based on the proposed scientific analysis to arrive at economically sound decisions on their purchase and use.

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■■

Research Project for State of Agricultural Machinery in Russian Federation

by

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I. GENERAL INFORMATION CONCERNING ALL MACHINES BEING USED IN EVERY COUNTRY (RUSSIAN FEDERATION, 2010)

Introduction

The essential influence for farm-producing efficiency is rendered by soil-climatic conditions of regions of Russia; almost all of them are in zone of risky farming, differing by fertility soils, landscape and productivity crops. For example, in 1999 on a background of sharp reduction of application of mineral and organic fertilizers, chemicals and fuel in Russian agriculture, only in 6 regions of the country the average yield of wheat was 2-2.5 t/ha, and average on the country -1.17 t/ha.

In 1991 seeded area was 115.5 Mha, including under grain and grain-leguminous, of which 61.8 Mha, has been brought chemical fertilizers on the average of 90 kg/ha and manure not less than 3.0 t/ha. During the period of 1997-2001, the application of chemical fertilizers application have been on the average of 15-19 kg/ha and manure at 0.9 t/ha or 4-5 times less.

For the period since 1991 for 2010, the seeded area in Russia has been reduced by 40 Mha which is not in use now.

The long-term practice shows that in the majority of regions for every five years, as a rule, three years are characterized by extremely adverse climatic conditions and poor crop yields.

So, in favourable years, gross output of grain has been 106.9 Mt in 1992 and 88.6 Mt in 1997 and 82.5 Mt in 2001; however, during adverse climatic conditions years: only 47.9 Mt in 1998, 54.71 Mt in 1999 and 65.4 Mt in 2000.

Successful design and development of the new agricultural machines mostly depends on the positive results of its testing in the different soil-climatic condition of the main developed agrarian regions of country.

The results of agricultural machines utilization on the farms during long period of time for all over the country also give us the information about the efficiency of machines and agro-technologies.

That is why there is a need to test all the machines in the different regions of Russian Federation where they should be used.

In Russian Federation, there are 10 Machine Testing Stations (MTS) mostly located in European parts of country in central and south regions of the Russia (**Fig. 1**).

As can be seen on the map, there are only two MTS on big territories in Siberian and Far East areas (FSBE "Siberian MTS", near town Omsk, and FSBE "Altayskaya MTS", near town Barnaul). It is clear that there are some real problems with agricultural production in North-East parts of Russia and first of all in "Mechanization zone I

Fig. 1 Layout of machine testing stations in Russian federation, 2012

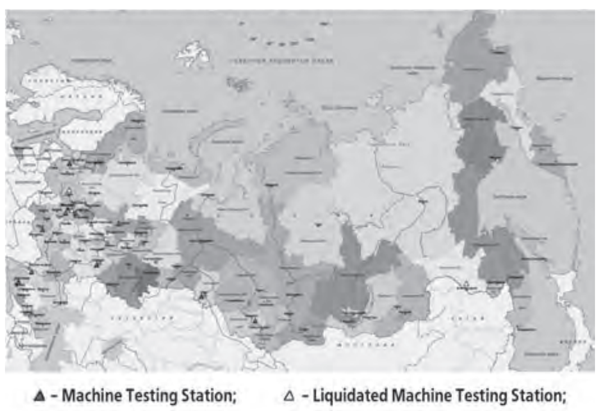


Fig. 2 Scheme of mechanization sectors of Russian agriculture

(**Fig. 2**).

However, there is a comparatively efficient agriculture in other zones mostly located in South regions.

The main and priority task for agricultural production is to supply food to the population for all over the country (good quality, ecological and healthy food).

However, during the last years, the Russian Federation has been importing more than 50 % of the necessary food in spite of the fact that we have so huge agro-recourses for food production (**Tables 1-3**).

The most important problem for increasing the food production in

Table 1 Total Recources Used in Russian Agriculture (1992, 1995, 2000, 2005, 2010)

Indices*	1992	1995	2000	2005	2010
Total arable land, Mha	130.0	127.6	119.7	115.4	115.3
Sown area, Mha, including area under:	114.6	102.54	84.67	75.84	75.2
- Grain and grain-leguminous;	61.94	54.4	45.6	43.59	43.2
- Forage crops, total, including:	42.5	37.06	28.9	21.6	18.1
- annual and perenial grasses;	30.02	28.868	23.99	19.49	16.14
-corn for silage, green forages,haylage;	9.54	6.15	3.67	1.57	1.5
- Sugar-beet;	1.44	1.09	0.81	0.8	1.16
- Potato;	3.4	3.41	2.84	2.28	2.2
Fallow ground, Mha	13.03	17.38	18.04	14.9	14.66
Mineral fertilizer used, mln.t,	10.1	1.5	1.4	1.4	1.9
Including per I ha, t/ha	89	17	19	25	38
Total fertilized area, %	66	25	27	32	42
Manure used, mln. t	347	127.4	66.0	49.9	53.1
Including per I ha, t/ha	3.5	1.4	0.9	0.9	1.0
Total fertilized area, %	7.4	3.2	2.2	3.4	7.5
Pesticides used, thousand t,	101.5	65.0	25.2	25.9	29.5
Total treated area, %	74.6	56.0**	32.66	45.3	46.0**

* Data from "Russia in Figures, 2011", ** Estimation.

Table 2 Main Indices of Agricultural production in Russia (1992, 1995, 2000, 2005, 2010)

Indices*	1992	1995	2000	2005	2010
Average yield of grain, t/ha	1.8	1.31	1.56	1.85	1.83
Gross grain output, mln.t	106.9	63.4	65.4	77.8	61.0
Average yield of sugar-beet, t/ha	19.2	18.8	18.8	28.2	24.1
Gross sugar-beet output, mln.t	25.5	19.1	14.1	21.3	22.3
Average yield of potato, t/ha	11.4	11.8	10.5	12.4	10.0
Gross potato output, mln.t	38.3	39.9	29.5	28.1	21.1
Average yield of vegetables, t/ha	14.5	14.8	14.3	17.0	18.0
Gross vegetables output, mln.t	10.0	11.3	10.8	11.3	12.1
Average yield of sunflow, t/ha	1.16	1.06	0.99	1.19	0.96
Gross sunflower output, mln.t	3.1	4.2	3.9	6.5	5.3
Average yield of soya-bean, t/ha	0.85	0.75	1.0	1.05	1.18
Gross soya-bean output, mln.t	0.5	0.29	0.34	O.69	1.22

*Data from Rosstat, "Russia in Figures, 2011"

Russia is a critical decrease in the domestic agricultural machinery manufacturing also the high level (up to 60 %) of the agricultural machinery imports (**Tables 4** and **5**).

The statistical data of agricultural tractors and mechanical harvesters/combines harvesters (responsibility of Russian representatives for coor-

Table 3 Seeded Area of the Agricultural crops in all Types of Agricultural Farms, 2010, Mha

Types of Farms	Total arable land, Mha	Including			
		Grain crops	Technical crops	Potato, Vegetables, Melon-field crops	Forage crops
All Agricultural Farms	75.2	43.2	10.9	3.0	18.1
Agricultural Enterprises	56.1	32.1	7.9	0.3	15.8
Private Farms	15.6	10.6	3.0	0.3	1.7
Population's plots of land	3.5	0.5	0.0	2.4	0.6

*Including Individual owners;

Table 4 The crucial cut down of Agricultural machinery Fleet in the Russian Agricultural Enterprises* for the period of 1992-2010 (thous. units)

Machinery and Equipment	1992	1995	2000	2005	2010
Tractors**	1290.7	1052.1	746.7	480.3**	310.3**
Moldboard Plows	368.3	237.6	148.8	87.7	
Cultivators	541.6	403.5	260.1	175.5	119.8
Drills	582.8	457.5	314.9	218.9	134.0
Harvesters:					
-Grain Harvesters	370.8	291.8	198.7	129.2	80.7
-Forage Harvesters	120.1	94.1	59.6	33.4	20.0
-Sugar-beet Harvesters (exclude tops cutting)	24.7	19.7	12.5	7.2	3.6
-Potato Harvesters	30.9	20.6	10.0	4.5	1.9
Mowers	208.2	161.6	98.4	63.9	41.3
Pick up press balers	79.5	65.1	44.0	32.4	24.1
Headers, swathers	218.7	152.2	85.2	46.9	27.0
Irrigation sprayers	69.5	46.3	19.2	8.6	5.4
Fertilizer spreaders	111.3	71.6	34.3	19.7	16.6
Inter soil manure applicators for:					
-Hard manure	80.0	48.8	22.0	10.9	6.5
-Liquid manure	38.6	26.2	12.1	5.8	3.9
Tractor sprayers and sprinkles	88.6	56.9	32.5	24.6	23.2
Milking machines and equipment	197.5	157.3	88.7	50.3	31.4

*Agricultural Enterprises without micro farms;
**Tractors without the special equipment for the road, ground and melioration works. The Agricultural Enterprises in 2010 have had 310.3 thous. units of agricultural tractors, the Private farms had about 70 thous. units, the Population farms had about 420 thous. units of the one axle motobloks of power –3-8 kW and of mass– 70-200 kg;

Table 5 Dynamic of cut down of technical provision for the Russian Agriculture with key machinery (units / 1000 ha) and specific annually field crops load for one machine (hectares/units)

Machinery and Equipment	1992	1995	2000	2005	2010
Tractors*	11	9	7	6*	4*
Field crops load, ha	92	108	135	181	236
Harvesters:					
-Grain Harvesters	6	6	5	4	3
Field crops load, ha	160	173	198	270	327
-Forage Harvesters	6	5	4	3	2
Field crops load, ha	170	210	240	330	450
-Sugar-beet Harvesters (exclude tops cutting)	17	18	16	11	4
Field crops load, ha	60	55	62	93	278
-Potato Harvesters	33	56	46	32	16
Field crops load, ha	30	18	22	31	62

*Tractors without of the special equipment for the road, ground and melioration works.

Table 6 The key machinery for the Russian Agriculture, 2010

Focus Area	Number in use (amount)	Source of data	Average Age (years)	Source of data
Agricultural Tractors	**310 300** ~ 63 % import from Belorussia and Ukraine; ~ 3.9 % from other countries;	Rosstat, 2011 Rosagromash	32% of tractors are of 10-17 years old;	Rosstat, 2011
Paddy Threshers	-	-	-	-
Hand Tools	-	-	-	-
Knapsack Sprayers	-	-	-	-
Combine Harvesters:				
-Grain Harvesters	**80,700** ~ 32 % import from Belorussia; ~ 15,2 % import from other countries;	Rosstat, 2011 Rosagromash	70 % of Grain Harvesters are above 10 years old;	Rosstat, 2011
-Forage Harvesters	**20,000** ~ 20 % import from Belorussia; ~ 18,2 % import from others countries;	Rosstat,2011 Rosagromash	65 % of Forage Harvesters are above 10 years old;	Rosstat, 2011 Estimation
-Sugar-beat Harvesters	**3,600** ~ 23 % import from Ukraine; ~ 12 % import from Belorussia; ~ 60 % import from other countries;	Rosstat,2011 Rosagromash Ministry of Agriculture	60 % of Sugar-beet Harvesters (domestic production) are above 8 years old; 40 % of imported Harvesters are above 10 years old and 60 % –up to 10 years old;	Ministry of Agriculture Estimation
-Potato Harvesters	**1,860** 25 % –Import from other countries and from Belorussia;	Rosstat, 2011	80 % of domestic production Potato Harvesters are above 10 years old; 20 % of imported Harvesters or assembled in Russia Harvesters are above 10 years old (localization ~ 5-20 %);	Estimation
Post-Harvest Machines				
Other machines	-	-	-	-
Total machines	-	-	-	-

Fig. 3 Structure of Agricultural Tractor Fleet of Russia (2004) (fleet -532 thous. units, and 412 -thous. units were above 10 years old)

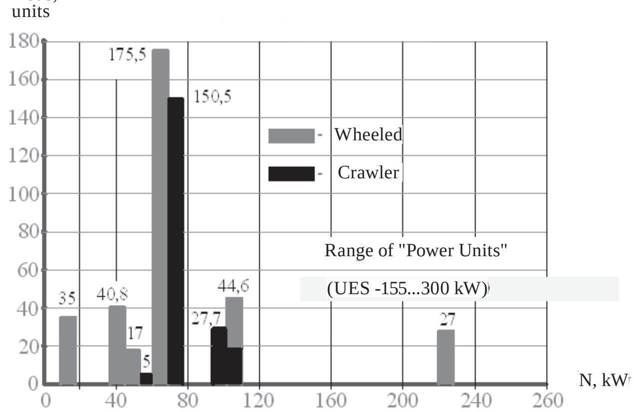
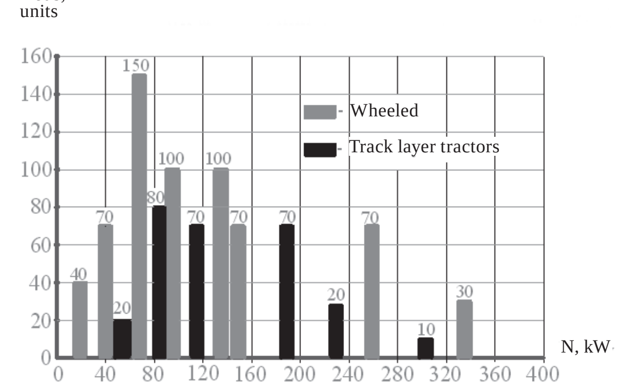


Fig. 4 Perspective range of Tractors for Russian agriculture, 2020 (fleet -900 thous. units, average power -110 kW, total sown area -90 mls. hectares, 10 units/1,000 hectares)



dination for tractors and participation in Mechanical harvesters) are placed in **Table 6**.

Addendum for tractors:

The tractor fleet for 2004 is shown on **Fig. 3**. The fleet had included tractors produced in Russia also traditionally imported tractors from Belorussia, Ukraine and Moldova. The fleet included 532 thousand units of the track-layer and wheeled tractors and from this quantity about 412 thousand units were above 10 years old. In 2010 tractors fleet was decreased up to 310.3 thousand units, while 63 % of this amount was imported tractors from Belorussia and only 3.9 % from other countries (USA– JD, CNH, AGCO; Germany– Fendt, Same Deut Fahr ….).

Fig. 5 Wheeled tractors and motobloks. Indicators of power and mass for different tractive classes (0.2-8)

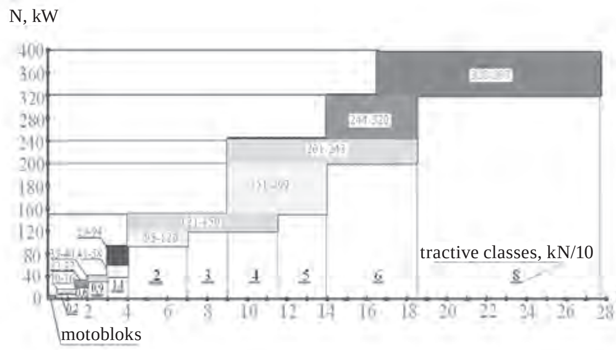


Fig. 6 Track-layer tractors. Indicators of power and mass for different tractive classes (2-8)

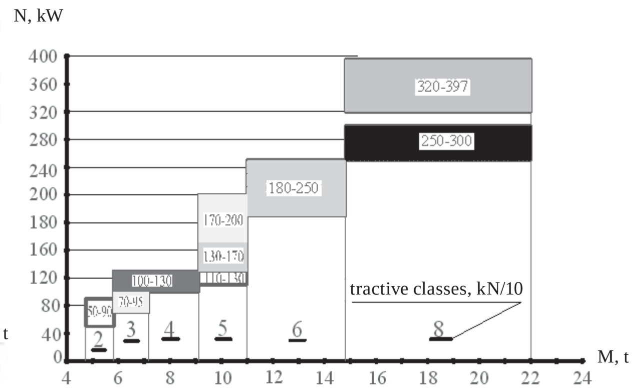


Fig. 7 Range of Grain Harvesters in Russian agriculture, 2010 (fleet -80.7 thous. units, 3 units/1,000 hectares)

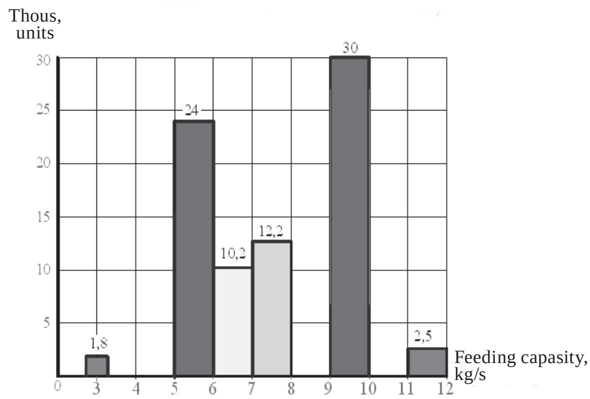
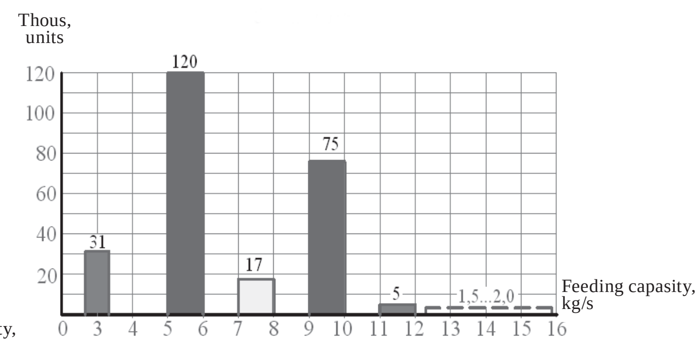


Fig. 8 Perspective range of Grain Harvesters for Russian Agriculture, 2020 (fleet -250 thous.units, grain crops sown area -44.43 mln. hectares, 6units/1,000 hectares)



*Source of data on **Figs. 7** and **8** - GNU VIM Rosselkhozakademii (Prof. Ed.V. Zhalnin)

Fig. 9 Range of Forage Harvesters in Russian Agriculture, 2010 (fleet -20 thous. units, 2 units/1,000 hectares)

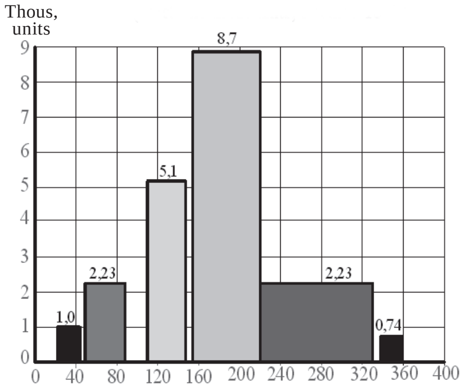
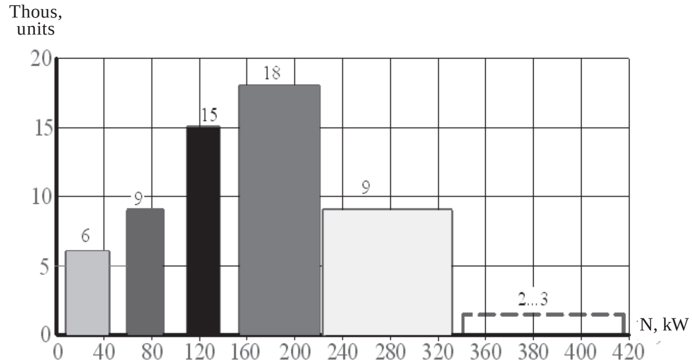


Fig. 10 Perspective range of Forage Harvesters for Russian Agriculture, 2020 (fleet -60 thous. units, forage crops sown area -13.48 mln. hectares, 5 units/1,000 hectares)



To solve the food security problems, it is needed to use annually about 90 milion hectares of seeded area on arable lands under most important crops. Also, there is need to improve some parts of natural grasslands (total ~ 20 Mha) and pastures (total ~ 60 Mha). That is why it is needed to recreate Russian agricultural machinery fleet and to increase significantly the domestic production in order to get for example, the perspective fleet of tractors by 2020 of not less than 900 thousand units of wheeled and track-layer tractors with average power of nearly 110 kW such that 10 units/1000 hectares (**Fig. 4**).

The perspective fleet of motoblocks, wheeled mini-tractors and tractors of tractive classes from 0.2 up to 8 (kN/10) is shown on **Fig. 5**. Track-layer tractors of 2…8 tractive classes are shown on **Fig. 6**.

Addendum for Harvester:

The range of grain harvesters for 2010 is shown on **Fig. 7**. The fleet of grain harvesters had only 80.7 thousand units (3 units/1000 ha), including the grain harvesters produced in Russia and traditionally imported from Belorussia (32 %) also in last years and from other countries (15.2 %): Germany: Claas, Fendt, Deut Fahr, Challenger; Italy: Laverda, Case IH; USA: JD, Massey Ferguson; Holland - New Holland; Finland: Sampo Rosenlew. The annually used harvesting area under grain crops should be increased up to ~ 44.5 million hectares. So, the perspective fleet of grain harvesters by 2020 should be about 250 thousand units of harvesters (6 units/1,000 ha) of feeding capacity

Table 7 Structure of forage harvesters fleet in russia (2010)

Country-producer		Classes of Harvesters Power, kW						Total %
		up 44	59-88	110-147	154-220	220-331	>338	
RUSSIA	self-propelled			PN-450 “Prostor” MARAL-125 AMUR-680 KSG-F-170A (10 %)	DON-680M ENISEY-324 MARAL-140 KSK-600 (JV) (assembling) (38 %)			~ 48 %
RUSSIA	Mounted							
RUSSIA	Trailed	KIR-1.5 (3 %)	PN-400 “Prostor” KSD-2 KKP-2 (10 %)	KSS-2.6 (1 %)				~ 14 %
BELORUSSIA	Self-propelled			KSK-100A-Б 8 %	KSK-600 (JV) (components)	KVK-800		~ 8 %
BELORUSSIA	Mounted **On the base of:** UES-250* UES-2-280** UES-290/450**	PALESSE-1* (1 %)	КРК-1400* (1 %)	КРК-2200* (1 %)	КРК-3000* (6 %) КНК-420**	КНК-420** КНК-500**		~ 9 %
BELORUSSIA	Trailed	КИН-1,5Ф (1 %)		КДП-3000П* (1.8 %)	КДП-3000П*			~ 2.8 %
OTHER COUNTRY	**Self-propelled** “CNH” (USA) “Claas”, (Germany) “Krone” (Germany) “John Deere”, (USA) **Trailed** “JF-Fabriken”, (Holland)			FCT-1050, FCT-1350 (~ 4 %)		Ягуар-830 Ягуар-850 Ягуар-870 (~ 7 %) JD 7200 JD 7300 JD 7400 (~ 4 %)	FX-40 (~ 0.2 %) Ягуар-890 Ягуар-900 (~ 2.5 %) BIG X V8 BIG X-500 BIG X-650 (~ 0.5 %)	~ 18.2 %
Всего, %		~ 5 %	~ 11 %	~ 25.8 %	~ 44 %	~ 11 %	~ 3.2 %	100 %

Types and shares of Forage Harvesters (%) at real fleet (20.0 thous. units) depends on Engine Power (kW) and Country-producer.
* Harvesters which were designed in Republic of Belarus together with Russian scientists and produced in Belorussia.
JV –assembling in Russia but components produced in Belorussia
** Complex of mounted harvesters (adapters for grain, forages, sugar-beet and grasses harvesting) on the base of Universal Power Units (**UES**) were designed together with Russian scientists and now are under production in Belorussia. **KVK-800** –the new design of Harvester;
“***Imported Harvesters***” *–CNH, JF-Fabriken, Claas, Jaguar, John Deere, FX, BIG X' Krone”.*

classes of 1-1,5, 3, 5-6, 7-8, 9-10, 11-12 and 14-16 kg/sec (**Fig. 8**).

The range of forage harvesters with a detail structure of forage harvester's fleet in Russia for 2010 are shown in **Table 7** and **Fig. 9** also the perspective range in **Fig. 10**.

The annually used harvesting area under forage crops should be increased up to nearly 13.48 million hectares. Thus the perspective fleet of forage harvesters by 2020 should be about 60 thousand units (5 units/1,000 ha) of power classes (15-30, 44-74, 88-147, 154-210, 220-331 and above 338 kW*). *Estimation.

The decrease of sugar-beet harvester's fleet from 1992 up to 2010 is shown on **Table 4**.

The detail structure of sugar-beet harvester's fleet shows that in 2010 from 3,600 units in the fleet, 2160 units (60 %) were imported from the following countries:

- USA– Amiti Technologi;
- Germany– WIC; Holmer; Terra Dos; Ropa; Franz Kleine; Euro-Mouse, etc.
- Ukraine– 24 %;
- Belorussia– 12 %.

The share of domestic production of sugar-beet harvesters were taken in the fleet only 5 % or 200 units.

The annually used sugar-beet harvesting area should be increased from 1.16 million hectares up to about 2.5* million hectares and for this the perspective fleet of sugar-beet harvesters by 2020 should be about 20 thousand units of different power classes (44…338kW*). *Estimation.

The decrease of potato harvester's fleet from 1992 up to 2010 is shown on **Table 4**. The detail structure of potato harvester's fleet shows that in 2010 from 1900 units in the fleet 1,440 units (76 %) were produced in Russia and Belorussia while:

- 320 units imported from Germany (Grimme ~ 17 %);
- Belgia– AVR (7 %).

The annually used potato harvesting area should be increased from 2.2 milion hectares up to about 4* million hectares and for this the perspective fleet of potato harvesters by 2020 should be about 30 thousand units of different power classes (88…330 kW*). *Estimation.

II. INFORMATION RELATED TO THE USE OF AGRICULTURAL MACHINERY (SOURCE OF DATA ROSTRUD", 2011 AND RUSSIA IN FIGURES", 2011)

Agricultural Tractors and Mechanical Harvesters/Combines

***The operations summary for the total numbers of injuries in 2010-2011 and of fatalities for Agriculture* also Hunting and Forestry are shown in* Table 8.**

The main reasons of fatalities in operating tractors, harvesters, transport and other equipment are that the machines are not in good conditions after repairing, poor knowledge of rules by operators and high daily working load of operators because of lack of tractors, self-propelled harvesters, tracks and transports in the Russian Agricultural Fleet and large annual load of tractors, harvesters (**Table 9**).

It is necessary to point out that for the last 20 years in Russian Agriculture, there were some different forms of agricultural producers: Agricultural enterprises of large and middle size (1,500-20,000 ha and more); Private farms (average 60-70 ha up to 200-400 ha) and Population of small plots of land (average 0.3-0.5 ha). In 2010, the agricultural enterprises used about 310 thousand tractors (16-350 kW), private farms used about 70 thousand tractors of 45-60 kW. The agricultural popu-

Table 8 Total numbers of injuries and fatalities

Sub branches of Economy	Code for OKVED	Total number of fatalities			
		2010		2011	
		Total	women	Total	women
Total in Russia		3244	244	3063	219
Agriculture*, Hunting, Forestry	A01-02.02.2	402	22	376	19

*There are no published statistical data separately for Agricultural Branch. So this is an estimate by taking into account only several (but most important technical and professional) of reasons caused of fatalities.

Table 9 The main reasons of fatalities in Russian Agriculture (2010-2011)

Agricultural machinery, equipment, conditions &rules	2010	2011
- constructive faulties and durability of machines out of order;	20	18
- use of machines after its repairing but out of order;	74	51
-violate of the rules of safety usage of tractors, self-propelled harvesters and transports in the agricultural areas;	67	63
-infringement of technological processes;	69	96
-not professional teaching of operators for safety labor;	90	80
-low professional management of technological processes;	10	15
Total ~ 82-86% from all fatalities in Agriculture*, 2010 -2011	330	323

Table 10 Subsidies (US$) to support of the Russian Agricultural Producers from Budget of Russia (95 %) and regional Budgets (not less than 5 %) for one farm (to pay off the 100% of the credit refinancing rate)

Types of Farms*	Types of credits		
	up to 2 years	up to 5 years	up to 8 years
Agricultural Enterprises	500 thous. $		1.333 mln. $
Private Farms	166.66 thous. $		333.33 thous. $
Population's plots	10 thous. $	23.33 thous. $	

*The profit taxation: 6 %, the taxation for individuals: 13 % from total income lations used mostly the one axle motoblocks (total amount about 420 thousand units of power ~ 3-8 kW and of mass ~ 70-200 kg).

Concerning the subsidies for every types of agricultural producers there are the different system of financing support (*Table 10*).

For Agricultural Enterprises:

- subsidies support on 8 years credits should be directed for payments for tractors, harvesters, agricultural machines and equipment, specialized transport for the deliveries of fertilizers, agricultural products, equipments for animal, poultry and forages for animal production and others.
- subsidies support on 2 years credits should be directed for payments for spare parts, and materials for repairing the machinery and equipments, material resources for greenhouses, agricultural animals, deliveries of fertilizers, pesticides, agricultural products, equipments for animal, poultry and forages for animals also for preliminary and industrial processing of meat and milk, etc.

For Private Farms:

- subsidies support on 8 years credits should be directed for payments for tractors, harvesters, agricultural machines and equipment, fertilizers, equipments for animal, poultry and animal production, equipment and pumps for irrigation, etc.
- subsidies support on 2 years credits should be directed for payments for fuels, spare parts, materials for repairing the machinery and equipments, material resources for greenhouses, forages for agricultural animals, fertilizers, equipments for animal, poultry etc.

For Population's plots:

- subsidies support on 5 years credits should be directed for payments for agricultural animals, small size agricultural machinery for the tractors with power less than 74kW, tracks for pay-load up to 3.5 tons, for repairing animal facilities, for processing of agricultural products etc.
- subsidies support on 2 years credits should be directed for payments for fuels, spare parts, materials for repairing the machinery and equipments, material resources for greenhouses etc.

The important problem connected with the crediting of farms is the risky level of the farm's profitability while taking in to account that non-profitable farms are consisted of ~ 27…30 % and low profitable farms ~ 32 % (**Fig. 11**).

The quotas of State budget expenditures for the period of 1991-2010 were drastically decreased from 36.9 % in 1991, 13 % in 1992 and less than ~ 4 % from 1995 to 2010 when in leading countries of the world such quotas are usually more than 20-30 %.

Dynamic of the financial support

Fig. 11 Scheme of supplying with agricultural techniques the farms of different level of profitability

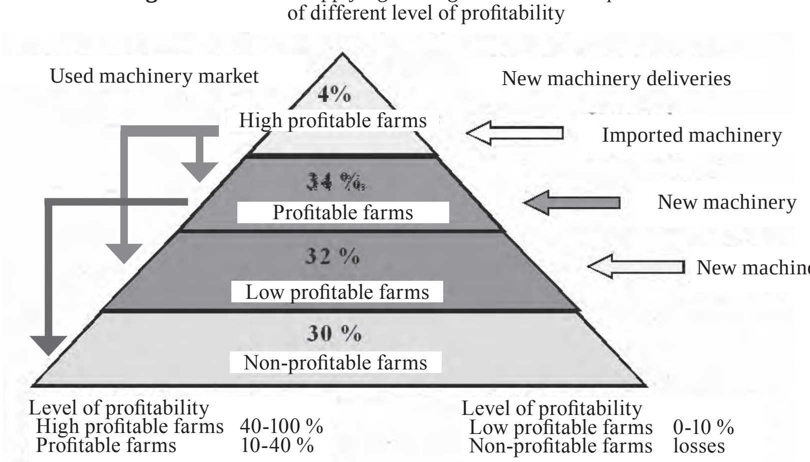


Fig. 12 Quota of state budget expenditures, capital investments of the Russian enterprises and foreign investments (billn.rouble) for supporting the Russian Agriculture

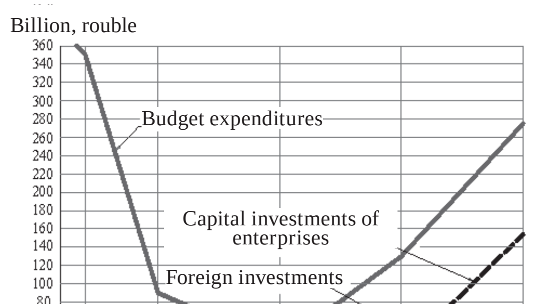
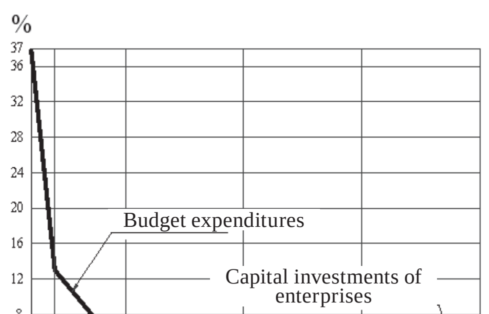


Fig. 13 Quota of state budget expenditures, capital investments of the Russian enterprises (%) for supporting the Russian Agriculture



of the agriculture from Russian Budget, capital investments from the different Russian enterprises and foreign investments are shown in billion Rubles (**Fig. 12**) and in percentage (**Fig. 13**).

Estimation of the social cost of injuries for the public and private sector.

The social role of high quality and working order tractors and harvesters should be supported by fact that in agrarian sector of economy every one, for example, tractor requires at least one qualified operator; also 5-6 additional workers to serve in agricultural infrastructure for all over the farm. Therefore, it is very important to prepare for future Agriculture that there would be the qualified operators for tractors, harvesters, transports and auto tracks while any death of of operators, there is big loss. It is very clear now that for the period 1991-2010, there was a loss of about one million tractors, ~ 300 thousand grain harvesters, ~ 100 thousand units of forage harvesters, etc. In total, the agricultural sector lost ~ 1.5 million units of tractors, harvesters and shut down job for 9-10 million workers.

Existence of testing procedures used in every country;

For all of the Russian Federation, there are 10 "Federal State Budgetary Enterprises "Machine Testing Stations (MTS)" (**Fig. 1**- map 1):

In European part of Russia there are 8 testing stations:

- FSBE "Podolskaya MTS" located in Moscow region close to Moscow;
- FSBE "Vladimirskaya MTS" located near town Vladimir near Moscow;
- FSBE "Central-Chernosem MTS" located near town Kursk.
- FSBE "Kirovskaya MTS" located near town Kirov (North of Russia);
- FSBE "North-West MTS" located near town Sankt-Petersburg ;
- FSBE "North-Caucasian MTS" located near town Postov-on-Don;
- FSBE "Kubanskaya MTS" located in Krasnodar region;
- FSBE "Povolzhskaya MTS" located in Volga river region, town Samara;

In Siberian part of Russia there are 2 testing stations:

- FSBE "Siberian MTS" located near town Omsk;
- FSBE "Altayskaya MTS" located in Altay region of East Siberia.

The coordinator of 10 MTS is Federal State Budgetary Enterprise: FSBE "**State Testing Center**", Moscow region, town Solnechnogorsk. All the Machine Testing Stations are under Ministry of Agriculture of Russian Federation and were accredited by "Federal Agency for technical regulation and metrology "***Rosstandard***". The MTS tests the all agricultural and forestry machinery produced by Russian's machine construction plants and also produced by foreign manufacturers. Ministry of Agriculture has the test plans for different kind of agricultural and forestry machines under the national and partly harmonized standards with OECD codes and IS0. The results of the tests machinery should be taken into account by manufacturers for improvement of their machines and also to get certificate for selling in Russia or for export. The testing/certification is going to show the results of machines tests to the manufacturers to go ahead with the improvement of machine and organization of the mass production of new machines also to permit them to sell the machinery to farmers if the machines are good and suitable to standards (to show the farmers the good indicators of performance of the machine, quality guarantee, to give the certificate to manufacturers to sell and export

Table 11 The loading of all-purpose power units UES-2-250/280 "Polesje" with complexes of harvesting machines "Polesje" at their intensive using (hours/ha)*

The cutting of annual grasses with KPK-3000	The cutting of grasses for the haylage with KPK-3000	The picking of the haylage with KPK-3000	The harvesting of the barley with KZR-10	The harvesting of the wheat with KZR-10	The preparing of the silage from the maize with KPK-3000	The harvesting of the sugar-beet with KSN-6	The harvesting of the maize for grains with KZR-10	The total loading of one UES, h/ha**
	200/600		120/200	220/400	300/375	200/300	200/400	1240/2275
	200/600		120/200	220/400	300/375	200/300	200/400	1240/2275
200/600		150/400			500/625	400/600		1250/2225
200/600		150/400			500/625	400/600		1250/2225
300/900		150/400			500/625	300/450		1250/2375

*The area of the harvesting annual grasses on hay -2,100 ha, the cutting and the lamination of grasses -1,200 ha and the picking of windrows for a haylage -1,200 ha, the barley -400 ha, the wheat -800 ha, the maize for a silage -2,625 ha, the sugar-beet -2,250 ha, the maize for grains -800 ha –the total volume of the harvesting works -11,375 ha;

**An average UES loading on the harvesting at the two-shift work -1,246 h/2,275ha; the factor of an intensification at the two-shift work –the factor of the increasing of machines loading over optimum terms of the harvesting, for example, different grain crops (the barley, the wheat, the maize for grains etc.) in one shift -260-280 h, at the two-shift work -540 h/1000ha. The factor of the intensification of the technological operations fulfillment ~ 2.

machines). Ministry has plans of all types the agricultural machinery tests with taking into account the specific soil-climatic conditions of the regions and zones of mechanization of Russian Federation (north, south, west and east on the territory of Russia) (**Fig. 2**- map 2).

***Collection of proposals for the better use of agricultural tractors and harvesters for development of the international testing system*.**

In a frame of OECD, ENTAM and ANTAM activities "The Center for cooperation with International Organizations for standardization, testing and certification of agricultural machinery" on the basis of VIM (The All Russia Research Institute for Mechanization in Agriculture) included in 2009 in ENTAM has connection with FSBE "Vladimirskaya MTS" and use the facilities of this station for testing new machinery work plans by VIM. Also VIM is coordinating the international activity of all MTS in Russia and represents them in OECD, ENTAM and ANTAM. Therefore, there will be possibility to test and certify the Russian machinery in ANTAM network in order to successfully sell the Russian made machines in Asia Pacific regions. Also to be sure that machinery imported from Asia Pacific regions is of high quality and durability since these were tested and certified in the network of ANTAM and it will provide aguaranty for Russian farmers. The information about the tests should be made available among other countries to show the possibilities and benefits of cooperation.

III. PROPOSALS FOR IMPROVEMENT OF THE MECHANIZATION SYSTEM IN RUSSIAN AGRICULTURE

Experience of decades of application in Agriculture of CIS countries; the new mobile universal energetic means (UES-2-250 /280 "Polesje");

First of all considering the most important problem for Russian Agriculture is to renew the Agricultural Machinery Fleet: increase wheeled and crawler tractor fleet up to 900 thousand units, grain harvester fleet up to 250 thousand units, forage harvester fleet up to 60 thousand units, sugar-beet harvester fleet up to 20 thousand units and potato harvester fleet up to 30 thousand units and, accordingly, many types of other machinery. It means that we should design, manufacture and annually test hundreds of new machines for all over country. Also there is a need to certifiy imported machines for selecting the most suitable machines for Russian Agriculture. All of this requires the huge capital, material, industrial and labor resources.

To save farm-resources and increase efficiency of agricultural machinery we recommended to USSR Government to work out the new concept of resources-saving complex on the base of universal

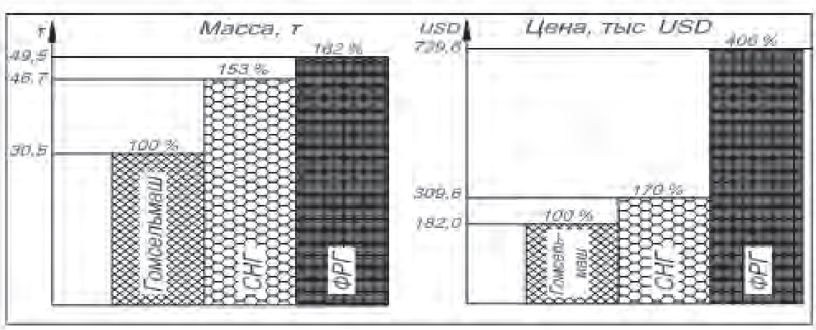
Fig. 14 The effective harvesting complexes on base of Universal Power Unit "UES-2-250A "Polesje" of power 250-280 HP (184…206 kW)

Forage harvester complex К-G-6 "Polesje"
with chopper and adapters for cutting green grass, haylage and silage from grasses and corn.
- productivity up to 90 t/hr

Rotary mower-crusher КPR-6 "Polesje"
with demountable conditioners for crushing of grasses and stacking two swaths.
- productivity up to 6 hectare/hr

Sugar-beet harvester КSN-6 "Polesje"
for one pass cuts tops, digs out, cleans and stacks Rotor"roots in a row between wheels of power unit.
- productivity up to 2 hectare/hr

Grain harvester complex КZR-10"Polesje"
with front mounted header and axial rotary thresh dram-separator also fastened behind to UES by the block of air-cleaning with a grain bunker.
- productivity on a grain up to 20 t/hr



Saving at least 16…20 tones

Saving at least of 127000 $

Main indices of efficiency of harvesting complexes on the base of UES-2-250A "Polesje" for forages, grain, sugar-beet, grasses for hay and haylage mobile power unit - multi-purpose UES-2-250/280 “Polesie” (184…206 kW) with quick-demountable high-effective harvesting adapters. The concept was realized in 1988-1996 and put under industrial production in Belorussia. Efficiency of removable adapters on the base of UES during harvesting season is shown in **Table 11**.

To the present time Belorussia produced ~ 10,000 complexes of machines on the base of UES-2-250/280 with 4 adapters: mower-conditioner, forage harvester, grain harvester, sugar-beet harvester - about 4500 complexes for Russia (**Fig. 14**).

It is necessary to attract attention of scientists and engineers also tests specialists of different countries with the aim to involve them in mutually interested activity for the new approaches directed to improve the system of mechanization (including the universal complexes of machines) and to raise the efficiency of global cooperation that will save resources, increase the income for every country and improve understanding with manufacturers of different countries to support the most economical ways for progress in World Agriculture.

New concept of powerful universal energetic means the double flow hydro-mechanical transmission (UES-290/450) –further UES-450;

On the basis of experience of decade’s application in Agriculture of Russian Federation, Belorussia, Ukraine, Kazakhstan and some other countries the complexes of UES-2-250/280 “Polesje” there were perspective machines on the base of more powerful UES-450 with engines of 290…450 HP (213…330 kW). Complexes include 8 new machines and adapters on the base of UES-450 and they were designed, tested and recommended for industrial production in a framework of the Russian-Belorussian Program of State Union in 2006-2009. The difference between two concepts consist of in replacement of hydrostatic transmission of UES -2-250A “Polesje” (tractive force ~ 20 kN) by the new type of double flow hydro-

Fig. 15a Complexes of 8 machines on the base of UES-450

Fig. 15b Harvesting complex on the base of UES-450

SELF-PROPELLED HARVESTERS		CHANGEABLE MACHINES ON UES-290/450	
	Self propelled mower-conditioner “COUGAR – 1400”	Mounted mower-conditioner “KPR-9-14”	
	Self-propelled Forage Harvester “DON-680M”	Mounted Forage Harvester “KNK-500”	
	Self-propelled Forage Harvester “DON-1500B”	Grain Harvester Complex “KZR-12”	
	Self-propelled Sugar-beet Harvester “ROPA”	Sugar-beet Complex “ASU-6”	
	Self-propelled Potatoe Harvester “Grimmer”	Potatoes Harvester “AKU-4” (in Project)	
	Wheeled Tractor Class 5, “K-744”	Multipurpose Universal power unit class 5, “UES-290/450”	

Fig. 16 Complexes of 8 machines on the base of USE-450

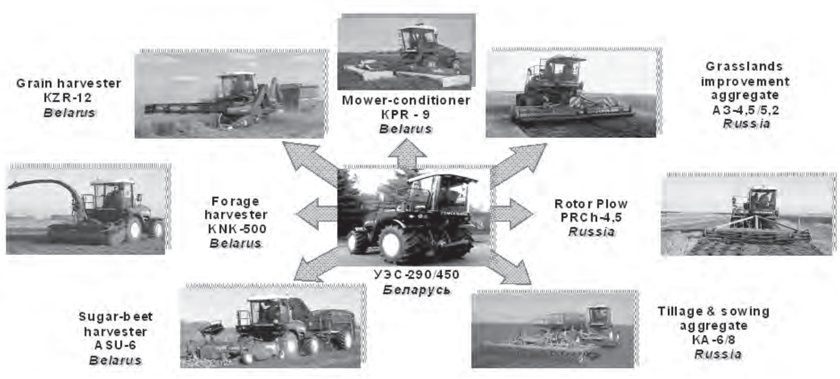
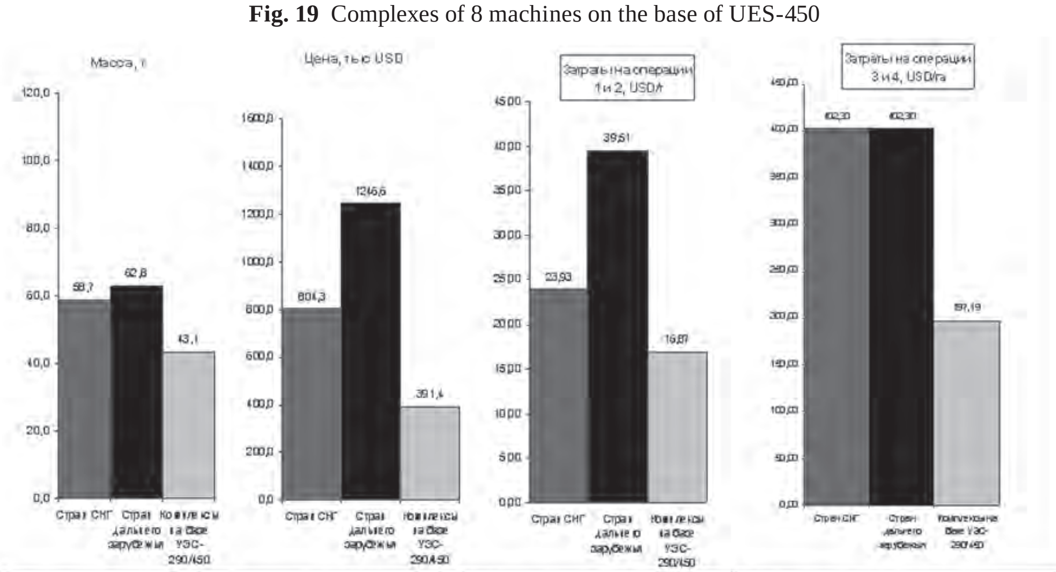


Fig. 17 The use of UES-450 on different kinds of works during 1200-1500 hours per year

Kinds of works	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Lording, h
Slot tillage, snow cleaning, snow accumulation		Cleaning								Slot tillage		snow accumu-lation	300
Loading and transportation of manures		Manure application											320
Silage loading from trenches										Silage loading from trenches			180
Grass sowing, haylage and silage harvesting				Sowing		Mowing	Harvesting						360
Grain and grainfodder crops sowing and harvesting				Sowing			Harvesting						250
Corn for silage and grain					Sowing				Harvest				260
Sugar-beet harvesting										Harvest			260
Potato harvesting									Harvest				230
Soil tillage			Tillage					Tillage					280
Grasslands and pastures improvement				Garssland improvement									280
Transportation		Transportation		Transportation							Trasportation		200

Fig. 18 Harvesting complex on the base of UES-450

Fig. 19 Complexes of 8 machines on the base of UES-450



Mass, T | Price thous. US$ | Harvest of grain & farage, US$/t | Harvest of sugar-beet & grass, US$/ha

mechanical transmission which allows UES-450 to successfully work not only with harvesting machines driven by PTO but also with plows, drills, tools and tillage-sowing aggregates which need the high tractive forces~50…60kN (**Figs. 15** and **16**).

Efficiency of application of new set of machines on the base of UES-450.

There are possibilities to successfully use power unit UES-450 at any time of the year (**Fig. 17**). The most efficient to use UES-450 with harvesting adapters (**Figs. 18** and **19**) instead of self-propelled harvesters, powerful and heavy tractors but also to use UES-450 with efficient agricultural machinery which are now under industrial domestic production and with imported machines that are used in Russian Agriculture (**Fig. 20**).

Total economical efficiency of complexes of 8 new machines on the base of UES-450 is

Table 12 Efficiency of complexes of 8 machines on the base of power unit (UES-450)
The prices and the mass of the new and the basic machines, $US ($US=30 Rub. Russian) and Ton

Complexes on the base of UES			Basic complexes (self-propelled or on the base of tractor)		
Name of machines or complexes	Price (thous. $US)	Mass (Ton)	Name of machines or complexes	Price (thous. $US)	Mass (Ton)
Complexes on the base of UES-290/450			**Existing complexes of comparable machines**		
UES-450 + KNK-500*	152 + 56.6	10.8 + 5.3	Jaguar - 850 ”Claas”*	370.3	13.7
UES -450+ KPR-9	152 + 51.7	10.8 + 3.8	Big M II “Krone”	244.4	13.5
UES-450+ KZR-12	152 + 127.8	10.8 + 10.2	TORUM-740	229	14.8
UES-450+ ASU-6	152 + 98.5	10.8 + 12.0	SF-10-2 “Kleine”	381.6	16.2
UES-450 + PRCh-4,5	152 + 32.6	10.8 + 2.5	John Deere + Falcland 3000 “Falc”	223.17 + 38.4	18.0 + 3.8
UES-450 + FM-5,2	152 + 40.0	10.8 + 3.2	John Deere + “Pantera – “Maschio”	223.17 + 56.7	18.0 + 3.1
UES-450 + AZ-5,2	152 + 45.0	10.8 + 5.4	(John Deere + Pantera – “Maschio”) + (Agrotron 150 + SLC-600)	(223.17 + 56.7) + (92.67 + 47.19)	(18.0 + 3.1) + (7.5 + 2.0)
UES-450+ KA-6/8	152 + 11.0	10.8 + 10.6	John Deere + Megaseed 6002 K2 “Rabe”	223.17 + 99.67	18.0 + 7.3
Total:	**(714.2)****	**63.8 (10.8 + 53.0)**	**Total:**	**(1783.1)****	**99.9 (18.0 + 81.9)**

shown on **Table 12** but comparison with machinery of CIS countries (mass, price and annual income) is represented on **Fig. 21**.

Present situation with key machinery at 2014 and prognosis to increase the machine-tractor fleet by 2020:

The fleet of main types of agricultural machinery from present crucial state (2014) to 2020 as prognosis:

- wheeled and crawler tractors from 2,597,000 units to 900,000 units;
- grain harvester from 679,000 units to 250,000 units;
- forage harvester from 161,000 units to 60,000 units;
- sugar-beet harvester from 25,000 units to 20,000 units;
- potato harvester from 26,000 units to 30,000 units;
- mineral fertilizer distributors from 163,000 units to 60,000 units;
- ploughs from 763,000 units to 400,000-500,000 units;
- drills from 1,154,000 units to 500,000-600,000 units and so on.

The Age indicators of key machinery in machine-tractor fleet by 2015.

~ 35 % of tractors of 10-17 years old;
~ 65-70 % of grain and forage harvesters of 10-12 years old;
~ 60 % of sugar-beet harvesters (domestic production) of 8 years old;
~ 80 % of potato harvesters (domestic production) of 10 years old.

Concerning the imported harvesters it is necessary to point out that ~ 50 % of them are above 10 years old and the level of localization of the assembled in Russia Harvesters is not more than ~ 5-20%.

Fig. 20 Tillage and sowing machines on the base of UES-450

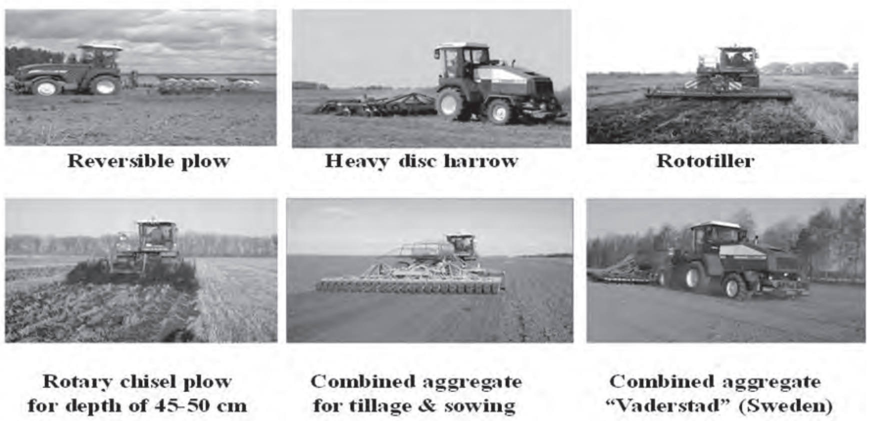
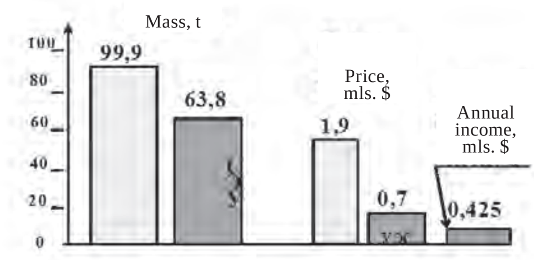
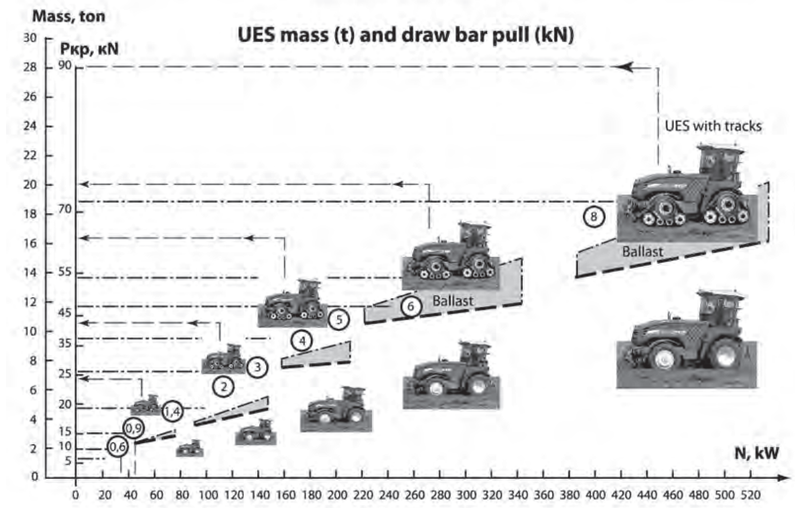


Fig. 21 Efficiency of complex of 8 machines on the base of UES-450 in comparison with CIS countries' machines



Toral annual income for one complex of machines on bese UES-450 is about 0.425 mls.$

Fig. 22 System of universal mobile power units: UES-60/100; UES-120/200; UES-210/280; UES-290/450; UES-500/700 (interval of power, HP)



Conclusions

Strategy for support of the food security in Russian Federation.

1. Strategy of UN FAO activity for the period 2000-2015 includes all the spectrum of social-economical, scientific-technological, trade-economical, natural safety, informational and other actions directed for a food security on the national, regional and international levels. "Every States should decide their food security problems on ***the national*** level. The most important aspect for this is to solve ***the agricultural engineering*** *issues and also ergonomic and environment problems by the way of introduction of the harmonized standards for machines and equipment";*

Table 13 Total number of self-propelled harvesters which can be replaced by UES System (**Fig. 22**) shown in **Table 12.** Manufacturing the possible number of UES will allow increasing the Tractor Fleet. Some indicators of UES efficiency: saving the material resources in 1.7…2 folds; decreasing the number of engines in 2.5-3 folds; saving the fuel ~ 30-35 %; releasing the qualified operators of tractors and harvesters about 10-11 thousand people, etc.

Interval of Power in kW	44-74	88 -147	154-206	213-331	368-515	Total replaced machines, thous. units
UES+Grain harvesting adapters instead of self-propelled Grain harvesters	+	+	KZR-10	KZR-12	+	230.0
UES+Forage harvesting adapters instead of self-propelled Forage harvesters	+	+	KNK-420	KNK-500	+	54.0
UES+Sugar-beet harvesting adapters instead of self-propelled Sugar-beet harvesters	+	+	KSN-6F	ASU-6	+	17.0
UES+Potato harvesting adapters instead of self-propelled Potato harvesters	-	+	+	+	+	25.0
Total self-propelled harvesting machines which could be replaced by UES with harvesting adapters	+	+	+	+	+	326.0
UES + different machines to work instead of tractors						230.0
						Total mass. t (%)
Mass of UES in class, t	~ 3.0	~ 5.0	**7.2**	**9.8**	~ 14.5	39.5 (100 %)
Average mass of Tractor in class, t	3.6..4.5	6.7…8.5	11.4…13.5	16.5…18.8	~22…27.7	68.9 (174 %)
Average mass of Harvester in class, t	4.0…5.6	9.1…11.2	12.2…15.6	14.5…16.6	~19.2...20.4	64.3 (163 %)
Specific mass of UES, kg/kW	~68…40	~56…34	**46…34**	**46…29**	~ 39…28	
Specific mass of Tractor, kg/kW	~82…60	~76…57	~74…65	~77…57	~60…54	
Specific mass of Tractor / Specific mass of UES, %	**136**	**151**	**175**	**182**	**173**	**136…182 %**
Specific mass of UES, kg/kW	~68…40	~56…34	**46…34**	**46…29**	~ 39…28	
Specific mass of Harvester, kg/kW	~ 90…75	~103…76	~79…75	~ 68…50	~ 52…39	
Specific mass of Harvesters/Specific mass of UES, %	**160**	**204**	**196**	**160**	**136**	**136…204 %**

2. To resolve the problem of food security by 2020, the Russian Federation should first of all start ***a real innovative rehabilitation*** of the industry on the base of high technological and technical levels in order to fill the machine-tractor fleet with the new machinery: 900 thousand tractors, 250 thousand grain harvesters, 60 thousand forage harvesters, 20 thousand units of sugar-beet harvesters and 30 thousand units of potato harvesters also many other machines (it will be enough for annually using of about 100 million hectares (from the total amount of 133 million hactares of arable land). Also there is a need to improve 10-15 Mha of grasslands and pastures (totally we have ~ 20 Mha of the natural grasslands and ~ 60 Mha of the natural pastures);

3. The Russian Federation, in spite of the fact that there are huge land resources available, has tried to solve the food security problems by importing of more than 50 % of food, more than 70 % of tractors, 40-50 % of grain and forage harvesters, 95 % of sugar-beet harvesters and many other agricultural machinery and equipment because of low domestic industrial, agro-technological and material-technical provision;

4. The specific power per unit hectare of arable land (kW/ha) including the total power of tractors, self-propelled harvesters and auto tracks used in Agriculture now is about 0.96 kW/ha. For tractor fleet only, at the average power of one tractor, 78 kW specific power is now about 0.4 kW/ha. It is not enough for successful Agriculture. So, for the perspective fleet for 2020, a specific power of total fleet per one hectare of arable land should be about 2.5 kW/ha but for the perspective tractor fleet only at the average power of one tractor 110 kW, the specific power may be ~1.5 kW/ha.

The priority ways to get out of the critical state of mechanization of Agriculture in Russian Federation.

1. For Russia, it is absolutely necessary to increase **the domestic industrial production of the key machinery** not less than by ten folds. This is the only way to support the development of productive and competitive agriculture as exclusive measure for increasing employment and income;

2. It is really impossible to fulfill successfully the prognosis of renewal of the Machine-tractor Fleet by 2020 because of:

- insufficient state of agricultural machinery manufacturing industry and high level of worn out machine-tools equipment in the most of machinery building plants as well as insufficient components base of domestic production, etc.
- lack of qualified workers for manufacturing the complicated machinery and destroyed system of professional teaching of technical operators to work in Agriculture;

3. Russian Agricultural producers has low solvency and much restrictions in getting budget investments and enough subsidies to buy the new machinery even the imported machines that are twice more expensive than the domestic manufactured machines (except of Belorussia production machinery).

4. The most economical way to go out from such a situation in Russian Agriculture consist of starting in large scale industrial production in Russia and Belorussia of the new complexes of machines on the base of universal power units UES-450 with the key adapters for harvesting forages, grains, sugar-beet, for tillage and seeding of different crops, for improvement of meadow and pastures with rotary tillers and engaging in different works by complexes machines and equipments during the all year round. It will give agricultural production the next advantages of UES-450 application:

- high yearly load of UES (1200-1500 hours) compare with har-

Table 14 New Forms of Farming and problems of Agricultural mechanization system in Russian Agriculture

Types and numbers of Farms	Main indicators of Agricultural production on the end of 2013				Main indicators of Agricultural production, prognosis to the end of 2020			
	Arable land, mln. hectares	Total agricultural product, %	Tractor Fleet		Arable land, mln. hectares	Total agricultural product, %	Tractor Fleet	
			thous. units	Average power, kW			thous. units	Average power, kW
Agricultural Enterprises, 24,000	56.1	48.7	259.7	73	90.0	77.7	900/329*	88-92
Private farms. 250,000	18.6	10.2	70.0	72.8	15.0	7.0	~400	66
Families plots, ~17.5 mln. families	3.4	41.1	412.0	2-5	5.0	15.3	2000 motobloks	12
Total:	78.1	100 %	741.7	~ 46	110.0	100 %	1300 + 2000 motobloks	

As far as the agricultural farms of different types and sizes were install also appeared the problems for supplying them with acceptable technique and technology. The parameters of existing forms of farming and main indicators of technical provision of them are shown in **Table 14**.

vesters (200-300 hours) decreases a specific cost of work ($/hour) by 4-6 folds;

• specific mass indicators (kg/kW) are very different for track-layer tractors (80-60 kg/ kW); wheeled tractors (70-55 kg/kW); self-propelled grain harvesters (90-50 kg/kW); self-propelled forage harvesters (70-50 kg/kW); self-propelled sugar-beet and potato harvesters (100-70 kg/kW) but the specific mass of UES-450 is 46-29 kg/kW.

It means that the total mass of complexes of adapters on the base of UES-450 are less in 1.7-2 folds compare with the mass of the set of self-propelled harvesters, tractors and other machinery on the tractor base;

• significantly decrease of a soil compaction (less losses of the crops yield) by using the front-mounted adapters and behind-trailed adapters when the total mass is spreads on the additional wheels of adapters (especially at working on wet soils).

It is anticipated that in future to design and place under industrial production the system of universal mobile power units with engines of 60/100; 120/200; **210/280*; 290/450*** and 500/700 HP (**Fig. 22**);*) **UES-210/280** and **UES-290/450** were already designed by Russia and Belorussia during 2006-2009.

5. The manufacturing, for example, of 100 thousand units of UES-450 (10-11 % of total perspective tractor fleet) with harvesting adapters also at ballasting and using changeable crawler type system for UES (**Fig. 22**, **Table 13**) will allow to replace in Agricultural machinery fleet: 100 thousand units of powerful tractors (10-11 % in fleet) also 40 % of Grain harvesters, 50 % of Forage harvesters, 80-85 % of Sugar-beet and Potato harvester's fleet; to decrease the numbers of diesel engines in 2.5-3 folds also decrease the fuel consumption by 30-35 %.

6. The system of UES can also be used in the communal and road-construction works in different branches of economy of Russia and CIS countries.

7. It is anticipated that the strategic problems of the Russian population with the competitive and ecological high quality domestic food products will also solvethe socio-economic problems in rural regions of Russian Federation.

8. These initiatives will also bring the real perspectives for the Russian Federation to be the leading country in the world with high efficient system of food production and with possibility to help other countries which suffer the food shortage.

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ABSTRACTS

The ABSTRACTS pages is to introduce the abstracts of the article which cannot be published in whole contents owing to the limited publication space and so many contributions to AMA. The readers who wish to know the contents of the article more in detail are kindly requested to contact the authors.

1267

Intelligent Dissolved Oxygen Control System for Intensive Carp System: Wael Mohamed Elmessery, Lecturer, Department of Agricultural Engineering, Faculty of Agriculture, Kafrelsheikh University, Kafr Elsheikh 33516, EGYPT; **Said Elshahat Abdallah,** Associate Professor, same. saidelshahat@agr.kfs.edu.eg

Success in designing affordable automated control systems for aquaculture will be widely applicable because it will enhance water management. Intensive recirculation systems have the potential for a significant increase in production per volume of water requiring dissolved oxygen monitoring and control. An intelligent Lab View dissolved oxygen sensing unit was designed using only one oxygen sensor and its transmitter for monitoring several tanks. Peristaltic pumps extracted water from each tank without adding oxygen to the sample. Measurements were auto-calibrated and statistically diagnosed using the air dissolved oxygen measurements. Dissolved oxygen sensor membrane fouling from algal blooms, sediments or suspended water droplets that still attaching to the membrane at the moment of oxygen measurements in the air were analyzed; the system controlled membrane fouling problems. Dissolved oxygen changes with temperature and fish feeding were analyzed from three tanks having each carps in a different growth stage. Dissolved oxygen mass balance was studied to gain a better understanding of events which can contribute to low dissolved oxygen concentration, such as heavy plankton blooms and high temperature.

1268

An Automatic Feeder with Two Different Control Systems for Intensive Mirror Carp Production: Said Elshahat Abdallah, Associate Professor, Department of Agricultural Engineering, Faculty of Agriculture, Kafrelsheikh University, Kafr Elsheikh 33516, EGYPT. saidelshahat@agr.kfs.edu.eg; **Wael Mohamed Elmessery**, Lecturer, same.

Feeding management provides the producer with an efficient tool to overcome limited feeding that may exhibit aggressive behavior during feeding due to limited feed availability resulting in carps that do not reach maximal growth. Overfeeding results in uneaten feed, poorer water quality, lower economic profit and additional environmental pollution. An automatic feeder was constructed and evaluated to provide predetermined amounts of food to four 9.5 m diameter tanks stocked with 7,000 organisms. Three tanks worked as rearing tanks and the fourth as nursing tank. Growth methodology optimized carp production in tanks which are grouped in four. These big tanks require of a better food distribution so three points of the tank were selected: two aside the edge of tank wall and another close to the center. Each point or wireless controlled gate provided the necessary food giving more chance to the fishes to obtain their provisions without competition. The system uses a hopper capable of feeding the four tanks during a week and its precision was dependant on a weighting mechanism. Two ways were used to control food provisions in this work. An opened control system based on the ATM89c51 microcontroller controlled the exact dosing based on the tank requirements according to the carp cycle and the other closed loop control system was determined by the conditions of water temperature, fish age, body weight and the amount of oxygen consumed. The amount of oxygen consumed by carps was the best parameter knowing fish metabolism and growth that the feeder can rely on it controlling meals provisions. The results show minimal differences in growth ($P < 0.05$) between treatments, important food saving of 25.337 % (equivalent to 3,495.5 kg), and lower water pollution (reduced water dissolved solids and ammonium components) compared with the first automatic feeder.

1307

Grading Process Intensification within Tilapia Fish Ponds: Said Elshahat Abdallah, Associate Professor, Department of Agricultural Engineering, Faculty of Agriculture, Kafrelsheikh University, Kafr Elsheikh 33516, EGYPT. saidelshahat@agr.kfs.edu.eg; **Wael Mohamed Elmessery**, Lecturer, same.

Despite the emergence trend of trying to mechanize all agricultural operations in Egyptian fields several decades ago. But that aquaculture still does not have any significant share in this direction through nursing, rearing, harvesting and even postharvest techniques. Tilapias grading is considered to be one of

ABSTRACTS

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the most important postharvest processes for marketing optimization. The main idea of manufacturing Tilapias grader is depend on the basics of fish behavior (attractive to current water (rheotactic)) by stimulating the Tilapias to trace the withdrawn water within the grader passed or retained through four sieves which have been placed in Tilapias movement course doing self-grading. Sieves sizes were determined according to preliminary study of Tilapias morphology. The relationship between Tilapias individual mass and its dimensions was obtained. Tilapia's depth and thickness were the main dimensions used to determine the Tilapias identity. Three levels of water discharging or water escaping velocity (100, 375 and 500 LPM) and two inclinations of grader raceway (5º and 7º) were investigated. The grader performance was demonstrated by studying the selectivity curve, selection range, individual mass mean selection and grading efficiency for each sieve. Maximum sieve grading efficiency achieved was of 97.87 % at 375 LPM and 5º grader inclination. Grader operational capacity was of 2,000 kg/h. This productivity can be achieved manually by eight workers for three hours. The behavior of each sieve (allow to pass or retain) during grading process towards each length or individual mass was modeled correspondingly with Logistic and Richard models. Richard model was found to be the best fit model for all the investigated sieves.

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EVENT CALENDAR

◆ **50th Croatian & 10th International Symposium on Agriculture**
February 16–20, 2015, Opatija, CROATIA
http://sa.agr.hr/

◆ **SIMA 2015**
February 22–26, 2015, Paris, FRANCE
http://en.simaonline.com/

◆ **49th Convention of Indian Society of Agricultural Engineers (ISAE)**
February 23–25, 2015, Punjab, INDIA
http://www.isae-pau.in

◆ **43rd International Symposium Actual Tasks on Agricultural Engineering**
February 24-27, 2015, Opatija, CROATIA
http://atae.agr.hr/Zbornik_2014.pdf for last year's proceedings

◆ **GFIA**—2nd Global forum for innovations in agriculture—
March 9-10, 2015, Abu Dhabi, UAE
http://www.innovationsinagriculture.com/

◆ **Efficiency of Mobile Machines and their Applications**
March 10-11, 2015, Braunschweig, GERMANY
https://www.tu-braunschweig.de/imn/emma

◆ **FRUTIC ITALY 2015 International Conference**
May 19-22, 2015, Milan, ITALY
http://www.aidic.it/frutic/main.html

◆ **XXXVI CIOSTA CIGR V Conference 2015**
—Environmently Friendly Agriculture And Forestry For Future Generations—
May 26–28, 2015, Saint–Petersburg, RUSSIA
CIOSTA– Commission Internationale del' Organization Scientifique du Travail en Agriculture was founded in 1950 and has organized many conferences, seminars, workshops and other meetings on the optimization of bio–production management and work, system engineering and innovative technologies. The theme of the Conference 2015 is “Environmentally Friendly Agriculture and Forestry for Future Generations” and is now calling for papers.
info@ciosta2015.org.

◆ **Indoor agriculture conference in Las Vegas**
March 31-April 1, 2015, Las Vegas, USA
http://indoor.ag/

◆ **GRAPAS International 2015**
June 9-11, 2015, Cologne, Germany
http://www.victam.com

◆ **2nd International Controlled Traffic Farming Conference Location to be confirmed**
June 14-16, 2015,
http://www.controlledtrafficfarming.com/Home/Default.aspx

◆ **New Frontiers of Biosystems and Agricultural Engineering for Feeding the Planet**
June 22-23, 2015, Naples, Italy
durso@unina.it
Submission of abstracts deadline 14th February 2015

◆ **10th ECPA Meeting**
—European Conference on Precision Agriculture Conference theme: Precision agriculture for efficient resources management under changing global conditions—
July 12-16, 2015, ISRAEL
http://www.ecpa2015.com/#!call-for-papers/c1cyg

◆ **GreenSys 2015**
July 19-23, 2015, Evora, PORTUGAL
http://www.greensys2015.uevora.pt

◆ **ASABE 2015 Annual International Meeting**
July 26-29, 2015, New Orleans Louisianna, USA
http://www.asabe.org/meetings-events.aspx

◆ **AgTech Summit**
July 2015, Salinas Valley, California USA
www.thecalifornian.com/...ag-tech-summit-salinas

◆ **Construction, Technology and Environment in Farm Animal Husbandry**
September 8-10, 2015, Friesing-Weihenstephan, Germany
http://www.btu-tagung.de/

◆ **Land.Technik AgEng 2015**
November 6-7, 2015, Hannover, Germany
www.vdi.de/landtechnik-ageng

◆ **4th CIGR International**
—AgEng Conference 2016– Robotics, Environment and Food Safety—
June 26-29, 2016, Aarhus, Denmark
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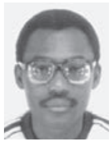
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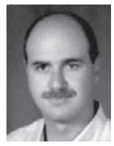
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Brian G Sims

Retirement Co-editors` Name List

Co-editor`s name	Nationality	Inaugu-ral year	Retired year
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Bala Krishna Shrestha	Nepal	1972	1991
Chul Choo Lee	Korea	1972	2014
Chau Van Khe	Vietnam	1972	1980
Manbahadur Gurung	Bhutan	1972	2006
Merle L. Esmay	U. S. A.	1972	1990
Giuseppe Pellizzi	Italy	1973	2012
Mohamed A. Bedri	Sudan	1973	1987
Shahansha-Uddin Choudhury	Bangladesh	1973	1991
T. B. Muckle	U. K.	1973	1978
Chang Joo Chung	Korea	1975	2014
T. Touggaard Pedersen	Denmark	1975	1990
Bilash Kanti Bala	Bangladesh	1976	1982
George B. Hanna	Egypt	1976	1988
Siswadhi Soepardjo	Indonesia	1976	1985
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Arumugam Kandiah	Ethiopia	1978	1989
Bherulal T. Devrajani	Pakistan	1978	2004
Satish Chandra	Fiji	1979	1990
Jitendra P. Mittal	Nigeria	1980	1993
Naresh Chandra Saxena	India	1980	1988
Paris Andereou	Lebanon	1980	1984
Wang Wanjun	China	1980	2012
Allan L. Phillips	U. S. A.	1981	2004
Julien G. Van Lancker	Brundi	1981	1989
Suppiah Kathirkamathamby	Sri Lanka	1981	1991
Armed Hossain Mirdha	Mexico	1982	1991
A. A. Valenzuela	Chile	1982	2013
David Boakye Ampratwum	Ghana	1982	2011
Kshirode Chandra Roy	Bangladesh	1982	1985
M. H. Abdel Aziz	Saudi Arabia	1982	1991
Krishna Prakash Srivastava	Ethiopia	1983	1989
Muhammad Siddique Chaudhry	U. S. A.	1983	1991
Wimala Tissa Weerakoon	Zambia	1983	1985
Harry D. Henderson	Lebanon	1984	1985
Mohammad Afzal	Pakistan	1984	1994
A. P. Kaloyanov	Bulgaria	1985	2013
Soedjatmiko	Indonesia	1986	2014
Aalbert Anne Wanders	Netherlands	1988	2007
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Chanchai Rojanasaroj	Thailand	1988	2011
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Eltag S. Eldin Mahmoud	Sudan	1990	2011
Henrik Have	Denmark	1990	2009
Abdulsamad Abdulmalik Hazza'a	YEMEN	1999	2014

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

(Vol.43, No.4, Autumn, 2012-)

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Vol.45, No.1, Winter 2014

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Vol.45, No.3, Summer 2014

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Vol.45, No.4, Autumn 2014

INSTRUCTIONS TO AMA CONTRIBUTORS

The Editorial Staff of the AMA requests of articles for publication to observe the following editorial policy and guidelines in order to improve communication and to facilitate the editorial process:

Criteria for Article Selection

Priority in the selection of article for publication is given to those that –

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b. are relevant: to the promotion of agricultural mechanization, particularly for the developing countries;
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g. art: supported by authentic sources, reference or bibliography.
h. written on CD-R.

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d. Complimentary copies: Following the publishing, three successive issue are sent to the author(s).

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c. The article must bear the writer(s) name, title/designation, office/organization, nationality and complete mailing address.

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j. Convert national currencies in US dollars and use the later consistently.
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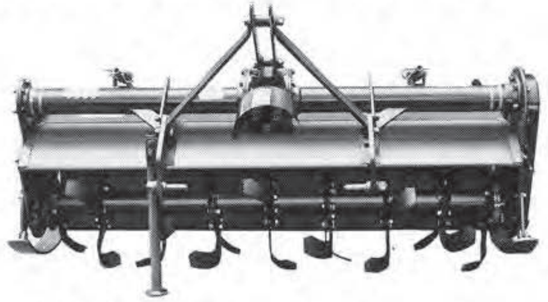

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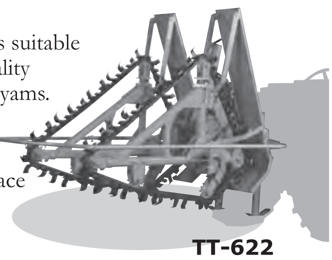

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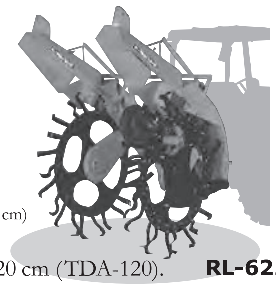

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