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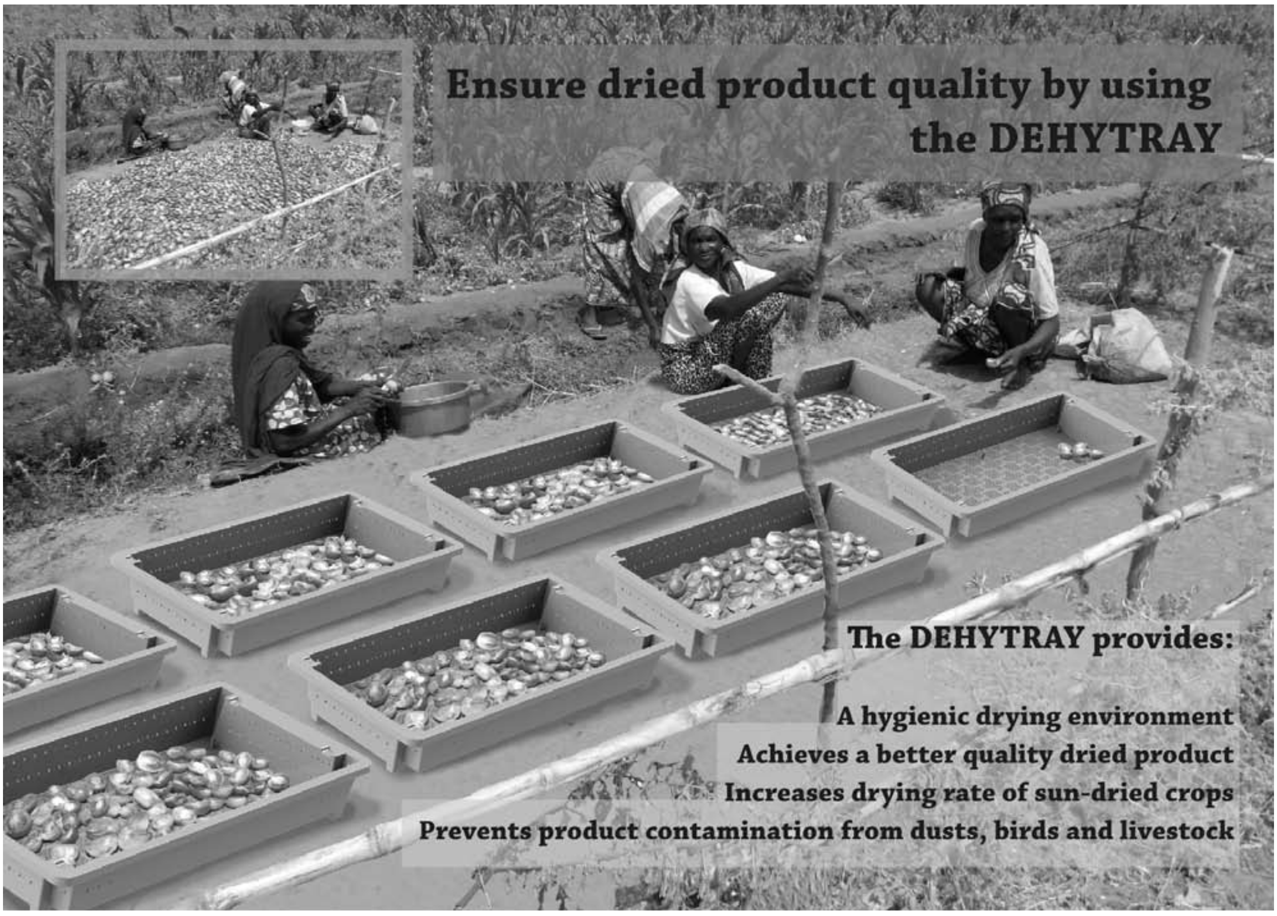
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EDITORIAL

Happy New Year 2018! We hope this year brings you a lot of happiness and success. Time flies. It's already the 18th year in the 21st century. Global population, which is now over 7.3 billion, continues to increase and will amount to over 9 billion in 2050. The growing number of population is accompanied by an increase in food demand, but the crop production between 2017 and 2018 is expected to almost equal to the one in last year. The following is roughly assumed production of each main commodity in 2017 (unit is ton) - Rice: 502 mill. Wheat: 743 mill. Maize: 1,054 mill. Sorghum: 59 mill. Oilseeds: 581 mill. Beef: 69,573 mill. Pork: 114,688 mill. Poultry: 117,717 mill. Dairy: 830,522 mill.

Currently, the workforce in agricultural sector is decreasing because of migration from rural to urban area and aging. It's an urgent matter especially in Japan. Nearly 80% of agricultural engagement is over 60 years and there's few expectation that additional workforce will come from other industries. If we want to hold agriculture as it is, we have to increase productivity by 5 times in 20 years. China faces similar problems. The share of urban population is increasing, rural areas suffer lack of labor force and the average age of agricultural engagement is over 63 years. The same things are going on in other countries. To solve these issues, we need to promote mechanization with unpreceded technologies. Completely innovative machinery such as an agricultural robot is sought in Japan. There was an agricultural machinery exhibition in Wuhan, China last October. It attracted 2,000 exhibitors and filled by lively air. Though the most of exhibitors were from China, there were a lot of large-sized tractors with high hp. Novel machinery such as radio controlled mowers were also exhibited. I was impressed by the momentum of agricultural mechanization in China and the force of its facilitators, agricultural machinery industry. The Agritechnica was also held in Germany in November. The trend of informatization was also seen there. Fendt showed the first swarm robots in agricultural machinery sector and received great attention. The robots can work as a group and seed corn. The trend of upsizing is still going on. Crawlers (tracks) have been widely used on big-sized tractors to prevent soil compaction from before and these are started to be used on many big-sized combines, too.

When I started the publication of AMA in 1971, we decided to develop appropriate agricultural machinery for farmers in the developing countries in cooperation with engineers all over the world. However, smartphone, a high technology item, is used not only in the developed countries but also in the developing countries. It means smartphone is an appropriate technology for people in developing countries. This fact urges us to reconsider what appropriate technology is that can readily be used in agriculture. In my opinion, agricultural robot with user-friendly interface and low-price will be the new appropriate technology for sure.

Let's improve new agricultural mechanization which uses new technology such as AI for agriculture.

Yoshisuke Kishida
Chief Editor
January, 2018

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Agricultural Mechanization in Southwestern China during Transitional Period: A Case Study

by
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Abstract

Southwestern China is now in transition from traditional agriculture to mechanized one. As a case, all mechanized farm operations in Chongqing were studied. Cultivation mainly relies on power tillers. Sowing, planting and harvesting are largely done using human power. Sowers are applied for producing rapeseed and potato; and transplanters and combines to rice. Small sprayers, threshers, rice mills, feed grinders, pumping stations and movable engine-pump sets are widely exploited. To some extent field transportation depends on humans and animals. Only small amounts of farm products are dried with machinery. Relevant problems were analyzed and recommendations were made in this paper.

Introduction

Southwestern China is composed of Chongqing, Sichuan, Guizhou, Yunnan and Tibet and possesses an area of around 2.35 million km^2. Its population was about 192.98 million (NBSC, 2011). The primary industry, i.e. agriculture, forestry, animal husbandry and fishery, contributed 8.4%, 12.3%, 12.7%, 14.2% and 15.9% of GDP in Chongqing, Tibet, Guizhou, Sichuan and Yunnan respectively in 2011, all higher than the country's average of 10.0% except Chongqing (NBSC, 2012).

Recently, the issue of agricultural mechanization in this region has got attention mainly due to the following reasons:

Firstly, rural people of the region have poured in cities, making labor shortage and some farm lands left uncultivated. A survey showed that until the end of 2006, in Chongqing 7,063 thousand of farm labors, accounting for 51.6% of the total, have left the original areas, involving 549 thousand ha of farmland, and the land uncultivated accumulated to 73 thousand ha of which about 60% were resulted from farmers' leaving (Maohua *et al.*, 2008). This causes farm labor cost to rise and using machinery becomes an economical choice. For example, for harvesting 667 m^2 of rice, the price of manual handling has reached 100-200 CNY (USD16.14-32.28) or more whereas it has cost within 100 CNY (USD16.14) to use harvesters (Maohua *et al.*, 2008).

Secondly, areas of mountains, hills and plateaus account for more than 2/3 of the total in China (Shian, 2001). This region has 54.2% of population but only 30% of GDP of the country. Among 31 provinces, autonomous regions and municipalities of Chinese mainland, there are eleven where the ratio of mountainous and hilly areas to cultivated land area is higher than 60% and the top four are all in the Southwest: Guizhou (95.6%), Yunnan (92.3%), Sichuan (91.4%) and Chongqing (85.3%) (Xiwen, 2011). Undoubtedly it is important to develop agricultural mechanization in the region for country's food security, growth of local economy and improvement of ecological condition.

Finally, a gap in agricultural mechanization, in terms of scale and speed, between the plain areas and mountainous and hilly areas, has been formed and further expanded (Xian, 2010). The crop comprehensive mechanization level of cultivating, seeding and harvesting (CCMLCSH) is usually used in China to indicate the level of agricultural mechanization. It is obtained by multiplying mechanization levels of cultivating, seeding and harvesting and their own weighted coefficients, 40%, 30% and 30% respectively, and then adding them together. In 2010, the State Council of China (SCC, 2010) set the country a goal of reaching 55% and 65% of CCMLCSH in 2015 and 2020 respectively. In 2011, the country's CCM-

LCSH was 57.17% and among 31 provinces, autonomous regions and municipalities of Chinese mainland plus the Xinjiang Production and Construction Corps, concerning the index, the first one was the Xinjiang Production and Construction Corps, achieving 91.54%, whereas Guizhou, Chongqing, Sichuan, Yunnan and Tibet came in the first, second, ninth, tenth and fourteenth from the bottom, only reaching 16.74%, 33.05%, 40.96%, 41.38% and 56.11% (AMMDMA, 2012) respectively, showing that the most main difficulty of China's attaining the set goal lies in improving the mechanization in the Southwest.

In 2007 the Chinese Ministry of Agriculture chose Chongqing as the first, only one until now, the Comprehensive Demonstration Base of Agricultural Mechanization of China (CDBAMC) (Yu, 2007), hoping the municipality to find out a way of accomplishing agricultural mechanization in mountainous and hilly areas.

Chongqing is situated at 105`17'-110`11' E and 28`10'-32`13' N, at the transitional area between the Qinghai-Tibet Plateau and the plain on the middle and lower reaches of the Yangtze River (Anonymous, 2007) and covers a land area of 82.3 thousand km^2. Its population was about 28.85 million in 2010 (NBSC, 2011). There are 560 kinds of cultivated plants, mainly rice, corn, wheat, rapeseed and potato (Anonymous, 2013).

Chongqing has two features, concerning agricultural mechanization. One is its topography. Mountains, hills and plains account 76%, 22%, and 2% of its territory respectively (Anonymous, 2013) while the other involves its relative developed manufacturing. Since its first power tiller was produced in 1998, the small agricultural equipment industry has developed. Over 200 enterprises now manufacture various farm power and machinery. Its output of the power tiller accounts over 70% of total in the country (Cheng *et al*., 2012). In 2011 it put forward a target of being the country's largest manufacturing base of small agricultural machinery in 2020 (Longju, 2011).

Having these two features gave the municipality advantages over other cities of the country in researching, developing, manufacturing, extending and improving small farm machinery.

Cultivation

Of all farming operations, cultivation is mostly mechanized. In 2011 mechanization levels of this operation for planting rice, wheat, corn, cotton, rapeseed, soybean, potato and peanut attained 93.26%, 89.61%, 86.28%,76.92% , 70.86%, 68.16%, 55.66% and 29.41% respectively(AMMDMA, 2012). This is largely due to the extension of Chongqing's original power tiller. The machine, being 51-150 kg and powered with diesel or gasoline engine of 2.2-6.3 kW, can achieve tilling depth of 10-16 cm, tilling width of 55-135 cm and efficiency of 220-540 m^2 h^{-1} (Jian *et al*., 2014). This kind of cultivator, mainly used for landscape gardening in developed counties, is primary mechanical implement for farm tillage in Chongqing.

However, following three problems exist in use of the machine:
1. High labor intensity;
2. Intense vibration (Ragni *et al*., 1999); and
3. Low efficiency.

In some plain areas or when opening up wastelands, farmers use large (>50 ps), medium-sized (20-50 ps) or small (3-20 ps) tractors with roto-cultivators or plows in order to obtain higher efficiency and profit or deeper cultivated soil.

Seeding and Planting

Machinery contributes a little to seeding or planting. In 2011 mechanization levels of the operation for rice, rapeseed and potato were 17.10%, 0.39% and 0.03% respectively, and sowing wheat, corn, soybean, peanut and cotton were almost completely done using labors with traditional tools (AMMDMA, 2012).

Two categories of machines are exploited to plant rice. One is the transplanter and the other is the sower. There are three kinds of transplanters. The first is the two-row walking transplanter, originally from Japan's ISEKI. It is about 90 kg, can be operated by a single person and is suitable to small fields, but has low efficiency, high price and is inconvenient to handle, due to the single wheel. The second is the KUBOTA's original four-row walking transplanter. It has advantages of high efficiency and being easier to operate but disadvantages of heavier weight, which make it more difficult to transfer. The last one, also originally from Japan, is the six-row riding transplanter. Being more comfortable to operate and having higher efficiency, it is welcome where the field and road conditions permit. In Chongqing, however, few areas can meet the conditions required and its application is very limited.

In a few farms the ten-row rice sower is used.

A lot of effort has been spent recently to extend rice transplanters, but with little effect. The main reasons are:
1. Irregularly raising seedlings;
2. Difficulties and troubles in adopting mechanical transplanting technology;
3. Lacks of technical workers or supplies of spare parts;
4. Inconvenient to transfer; and
5. High price.

Occasionally rapeseed is sowed with four-row seeders and potato with two-row seeders.

Inter-cultural Operations

Three types of sprayers are used to prevent and control plant diseases, such as the rice blast, and eliminate pests, such as the borer. The manual sprayer is cheap, portable, but not so good in spraying quality. The second one, being about 11 kg and powered by a gasoline engine of around 1 kW, with relative high efficiency and good spraying quality, is often used to deal with single disease or pest on large areas. However, it makes noise and is easily damaged. And the last one, the electric sprayer powered with batteries of 12 V, being about 5 kg and having a working pressure of about 0.4 MPa, is convenient to use and has a good performance. But the durability of the battery is in need of improvement.

In 2013, one kind of small pilotless helicopter was introduced for spraying and got attention. The machine, powered by batteries, controlled on ground, carrying 5-10 liters of chemicals and costing 40-100 thousand CNY (USD 6.46-16.14 thousand), is suitable for mountainous and hilly areas. However, its single function, high price and short lasting working time will probably hamper its spread.

Basically, there are not appropriate machinery for weed control and fertilization.

Harvesting and Threshing

There are a wide variety of harvest methods, including using labors, animal power, harvesters, combines and their combinations. In 2011, the mechanized harvesting level of rice was the highest, reaching 35.94%; followed by that of wheat, 3.62%; of rapeseed, 0.19% and of potato, 0.02%. Other crops, such as corn, soybean, peanut and cotton are almost totally harvested with traditional tools (AMMDMA, 2012).

The two, four or six rows of semi-fed or full-fed combines mainly originally from Japan's KUBOTA, YANMAR and ISEKI are utilized to harvest rice and wheat in plain areas, because of their high efficiency, good performance and convenience to operation. However, there are two problems with them when applied in the area. One is they cost too much and the other is they are too heavy. In Chongqing there are some paddy fields where the water is not drained away during harvest season. So they are too soft to bear combine's weight. In addition, because usually there are not tractor roads, it is very difficult, even impossible to transfer the machine. In some cases, it expended more time in transferring than in harvesting. Therefore, Chongqing's origin two-row full-fed combines are commonly used in mountainous and hilly areas, owing to their light weight, relatively convenient to transfer and cheapness. However, their performances are still in need of improvement, though an obvious and steady progress has been made.

Only small parts of rapeseed and potato are mechanically harvested. Main problems are that the machine produces more rapeseed loss compared with manual harvest and the potato harvester cannot be adapted well on sloping fields and heavy and sticky soil.

Corn harvesting with machines has just been under way. Various soils, weathers, species, cropping methods and corn uses have brought troubles to the development and application of harvesters.

There are two main types of threshers commonly utilized. One is powered by a small gasoline or diesel engine or electric motor of 1-2 kW for processing rice and wheat in fields and the other is usually powered by an electric motor of below 1 kW for corn threshing in courtyards.

Rapeseed is mainly threshed with traditional methods.

Irrigation

Irrigating equipment plays an important role. This is because:

1. Rainfall usually can not meet the requirements of plants for water, there are frequent droughts, and therefore rice, vegetables, fruits, etc. must be irrigated; and
2. A large number of farming fields are higher than rivers, reservoirs and ponds.

Since 1960' a lot of small pumping stations have been built. Usually each of them is electrically powered with less than 1 MW and provides less than 10 m^3/s of water. Multi-stage stations are often needed for a high pump lift. Occasionally it is higher than 100 meters. In 2011, there were 3,609 stations, 891 thousands motors and 954 thousands pumps (CMBS & NBSSOC, 2012). However, of existing stations, 60% have been used for more than 30 years, 40% are ill-equipped perennially and 15% can not work any more (Maohua *et al*., 2008). As a result, reduction of crop output will occur when drought arrives. Therefore, the reformation of pumping stations which began in about 2000 remains a task to be fulfilled.

As a supplement, movable gasoline engine (about 1kW)-pump sets, are widely utilized, especially during drought seasons.

It was estimated that 447.43 thousand hectare of areas were irrigated with pumps in 2011 (AMMDMA, 2012).

Three types of equipment for water-saving irrigation, i.e. sprinkler, drip and micro sprinkler irrigation are utilized, mainly in greenhouses or for vegetables and fruits. However, they covered only 27.32 thousand hectare in 2011 (AMMDMA, 2011). Main reasons lie in their high cost for both construction and operation and the irrigating system being easily blocked or damaged.

Replacement of canals with pipes is currently a saving water irrigating technology most widely extended.

Transportation

Transportation within and between fields, and between farmer's house and fields, depends on labors, animals, motorcycles, rickshaws, electric cars, tractors and automobiles. However, manual handling and animal power still account for a considerable share. Currently only older people, women and children have remained for doing farming works. Carrying goods has become a serious problem to be urgently solved, especially fruits, because fruit trees are usually planted in mountains and hills where transportation is more difficult. For this issue, cableway, monorail and double track have just been introduced for test and demonstration. However, owning to their high cost and commonly quite irregular orchards, a considerable work has to be done for the application of these technologies.

Drying

Natural drying methods are still mostly used. The tower dryer and rotary dryer are primarily for rice and corn. The cash crops, such as chili, pepper and Chinese herbal medicine, such as coptis and honeysuckle are dried with locally made equipment.

Processing Operation

Although there are various farm products, those processed are limited. Small mills and grinders are mostly utilized. The former are used to process rice for food of farmers themselves, and the latter to process corn for producing pig feed.

Main Problems

Since Chongqing became CDBAMC in 2007, its CCMLCSH rose from 13.23% then to 33.05% in 2011, demonstrating a considerable headway has been made. However, the course is now confronted with several difficulties. This is manifested in the fact that farmers' increasing requirements for power and machinery, in terms of their types, quality, reliability, prices and performance, resulting from the decreasing labors and the increasing demand for crop output, can not be met. The main reason is that after seven years, except for the last increase in agricultural machinery subsidies from governments since 2004 when the Agricultural Mechanization Promotion Law was passed, the following nine problems have not been solved, even to some extent remain unchanged.

1. Fields are commonly small, irregular and scattered on terraced hillsides, and some of them are soaked in water perennially.
2. Mechanization infrastructure is generally seriously imperfect.
3. Farmers' capacity for purchasing machinery is very limited.
4. A majority of farms are not specialized.
5. The land area per household is small and farmers' lands are usually separated into several different parts.
6. There are a variety of soils, species, cropping modes and crop uses.
7. Machinery and agro-techniques do not match each other well.
8. Service system is in need of construction or improvement.
9. The capability to innovate, research and develop farming machinery is very limited.

Recommendations

For further promotion of agricultural mechanization in Chongqing, it is absolutely necessary to match well all essential elements of agricultural production system when the machinery is introduced.

Mountainous and hilly areas in Japan, South Korea and Chinese Taiwan as well as Chongqing account for 2/3 or more of their own total. The three have early successfully realized agricultural mechanization. Their experience is worth for reference, because the problems Chongqing is facing today are almost exactly what they had previously faced.

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Development and Performance Evaluation of A Hydraulic Press for Animal Feed Blocks Formation

by
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Abstract

An appropriate machine prototype was developed and evaluated for densification of rice straw with molasses into animal feed blocks, to enable efficient utilization of rice straw, and to improve the feed bulk handling, transportation, and storage properties. The prototype machine involved two main parts namely: hydraulic press and compactor parts (mold, rammer and free base). The raw material feed samples were densified under the effects of four pressure levels (24.52, 34.32, 44.13 and 53.94 MPa), two geometrical mold shapes (cube and cuboid), four molasses content levels (4, 6, 8 and 10%), and three moisture content levels (about 10.32, 13.41 and 16.58%, w.b.) by a piston-mold process. The properties of the densified animal feed blocks were illustrated with respect to bulk density, densification degree, resiliency, durability and stiffness. Also the performance of densification prototype machine was evaluated in terms of its productivity and cost unit. Results indicated that the optimum conditions for producing good quality densified feed blocks were obtained by applying hydraulic pressure of 53.94 MPa, molasses content of 10% and straw moisture content of 16.58%. As densification process was carried out respectively in cube and cuboid molds under these variable levels, the produced feed blocks exhibited respectively: bulk densities of 659.87 and 632.04 kg/m^3, densification degrees of 281.41% and 265.32% and resiliency of 8.35% and 10.03%. The results also indicated that the highest durability values of 99.27% and 96.92% were respectively obtained for both densified cube and cuboid blocks at moisture content of 10.32%, compression pressure of 53.94 MPa and molasses content of 10%. At the same mentioned densification conditions, the highest block stiffness values of 385.22 N and 380.86 N were obtained respectively for both densified cube and cuboid blocks. For choosing a proper geometrical mold shape, the results reveled that the densified cube blocks were high stability compressed blocks compared to cuboid blocks. The average productivity of the investigated feed block formation equipments was 60 feed block/h (45 kg/h) while, the machinery unit cost was about 8.144 LE/h (0.18097 LE/kg).

Introduction

Crop production in Egypt has achieved new feats. This has simultaneously led to increased production of crop residue (e.g. rice straw), which are usually considered as waste despite their huge potential for utilization as fuel, feed and chemicals. The major problem associated with the residues is their low bulk density, which causes a serious problem in their handling and transportation. This leads to the problem of residue disposal during the harvest season. Consequently, most farmers prefer to burn it in the field, which leads to environmental pollution and loss of income that could otherwise be realized through their potential use. It is, therefore, felt that densification of these residues to an economical level is very important for their further use. There are several densified technologies like briquetting, pelleting and baling which are in use in Egypt. However, these processes have been found to be useful for crop residues only to a limited extent. In a hunt for a better process, animal nutrition experts, through previous researches have suggested that the crop residue could profitably be used as animal feed by mixing with diet supplements like concentrates, molasses and mineral mixtures and densifying the mixture (AbouElmaged *et al*., 2003; AboSalim and Bendary, 2005 and

Ghanem *et al*., 2005). However, lack of a suitable machines for crop residues densification into animal feed blocks. O'Dogherty and Wheeler (1984) studied the compression of straw and grass in the closed dies at pressures in the range of 12-31 MPa and established a pressure density relation for the straw and reported the optimum moisture content for the wafer formation as 10-20% (w.b.). Ferrero *et al.* (1990) reported that the pressure-density behaviour of wheat, barley and rice straws of different moisture contents during compression in a cylindrical die at pressures of 20-100 MPa. It was also reported that up to 6MPa pressure range, the relationship between density and pressure was linear, beyond which nonlinear relationship appeared. Durability or abrasive resistance test simulates either mechanical or pneumatic handling. These tests can help control the densification process and thus, block quality in the feed manufacturing industry. In the feed industry, high durability means high quality blocks (Kaliyan and Vance Morey, 2009). Al-Widyan *et al.* (2002) studied the quality of the densified products in terms of briquette/pellet durability and stability. Highly durable and stable pellets/briquettes are less susceptible to breakage during handling, transportation and storage. A durability index is determined to simulate the ability of pelleted and cubed material to withstand the impact force and vibration generated during handling. Stability is the ability of the product to maintain its initial dimension and shape. Ndiema *et al.* (2002) reported that there was considerable influence of the die pressure on the size and form of briquettes. For a given die size and storage condition, there was a maximum die pressure of 80 MPa beyond which no significant gain in the cohesion of briquette could be achieved. Singh *et al.* (2002) reported a minimum 4-5 times increase in bulk density of roughage-based feed materials, with an increase in compression pressure from 21 to 42 MPa during the densification process in the form of blocks. Compaction is the process of densification that decreases the pore size and porosity and causes particle rearrangement by means of impact energy. The compaction of agricultural residues is a value adding process. Compaction of straw from different crops, with additives of molasses, minerals, concentrates and other diet supplement, into animal feed blocks and pellets is highly useful in animal nutrition management, transportability and storage. Nutritionally, molasses is used as an energy source. Molasses is a useful ingredient for improving the palatability/digestibility of the diet and serving as a binder. In pellets or blocks production for animal feed, binders are allowed but need to be specified as part of the final product. Examples of good binding materials are molasses, starch, fish waste, manure and maize or wheat bran. Compaction of fodders and straws into large blocks could save the storage space and transportation cost by the same factor as achieved in the compaction process (Sarwar *et al*., 2002; Khan *et al*., 2003 and Tumuluru *et al*., 2010). Therefore, the general objective of the present study was to manufacture and evaluate the densification performance of local equipments for animal feed block formation from rice straw, while the specific objectives were:

- Develop a vertical hydraulic press with a piston/mold parts as densification prototype machine.
- Determine the optimum conditions for densification, with respect to applied hydraulic pressure level, moisture level, molasses additive level and also the geometrical shape of formation mold.
- Evaluate some the physical properties of the compressed blocks.
- Estimate the productivity and unit machinery cost of feed block formation equipments.

Materials and Methods

The densification prototype machine was developed based on the principle of hydraulic compression for making feed blocks. Whereas, a vertical hydraulic press with a piston-mold equipment was used as the compactor.

Hydraulic Press, Molds and Rammers

A hydraulic press is a machine using a hydraulic cylinder to generate a compressive force. The Japanese type hydraulic press (Model No., HP-50E) was used in this work. It consisted of a cylinder fitted with a piston that uses fluid (hydraulic oil) under pressure to exert a compressive force upon a stationary anvil or base plate. The fluid is forced into the cylinder by a pump. Hydraulic press includes four legs mounted on a pair feet connected at the bottom by a cross brace. It has loads capacity to apply pressure up to 58.48 MPa (600 kg/cm^2). Molds and rammers were manufactured to form the animal feed blocks. These were fabricated at private workshop in Kafrelsheikh Governorate, Egypt. Two geometrical shapes of mold namely: cube and cuboid were used in this research. Molds were built from iron sheet with 4 mm thick. The dimensions of the cube mold were 17 × 17 cm of cross-sectional area and 15cm high. Four cubic molds were formed and were constructed as one unit to produce four blocks of animal feed at the same time. While, the cuboid shaped mold had a cross-sectional area of 12 × 24.083 cm and 15 cm high. Also, four cuboid shaped molds were formed and were fabricated as one unit to produce four blocks with each other. Two molds (cube and cuboid) have equal values from the calculated area and total volume. The plungers were constructed of the welded steel angles 50 × 50 mm with four rammers from flat iron sheet (5 mm thick) to fit into the compaction molds for load application. The vertical load was applied manually on the sample until the desired pressure level was achieved. The pressure was read off the dial of a pressure gauge. The block samples were made by compressing the rice straw/molasses with a piston and molds assembly. These procedures are done by placing the molds on the table of the hydraulic press, aligning the plungers/rammers with the location on the molds where the procedure needs to be done and placing the piston into motion (manually) and the procedure is accomplished **(Figs. 1**, **2** and **3**).

Raw Material

Rice straw (Sakha 101 variety) samples were collected and dried in a solar dryer (passive aeration type) until the desired moisture contents of about 10.32, 13.41 and 16.58%, w.b. was obtained. The dried straw samples were chopped into about 1-3 cm segments to be tested in all the experimental treatments. Different proportions of sugarcane molasses (4, 6, 8 and 10%, from mass of rice straw) were mixed with rice straw for various its moisture content. It was regarded that the maximum molasses content was kept such that no oozing of molasses was caused through application of high pressure level. To study the optimum conditions for densification and also the compression characteristics for rice straw with molasses, special regime of experiments were carried out during the year of 2014 at Rice Mechanization Center, Meet El-Deeba, Kafrelsheikh Governorate, Egypt.

Investigated Variables:

The plan of the group of experiments was essentially designed and carried out to acquire some indicators which would evaluate the piston-mold process by the hydraulic press. Those indicators are the physical characteristics of the compact blocks, such as bulk density, densification degree, resiliency, durability and stiffness under the investigated variables. The Investigated variables and their levels were as follows:

- Two geometrical shapes of mold namely: cube and cuboid;
- Four compression pressures of 24.52, 34.32, 44.13 and 53.94 MPa;
- Four molasses content of 4, 6, 8 and 10%. and,
- Three moisture content of rice

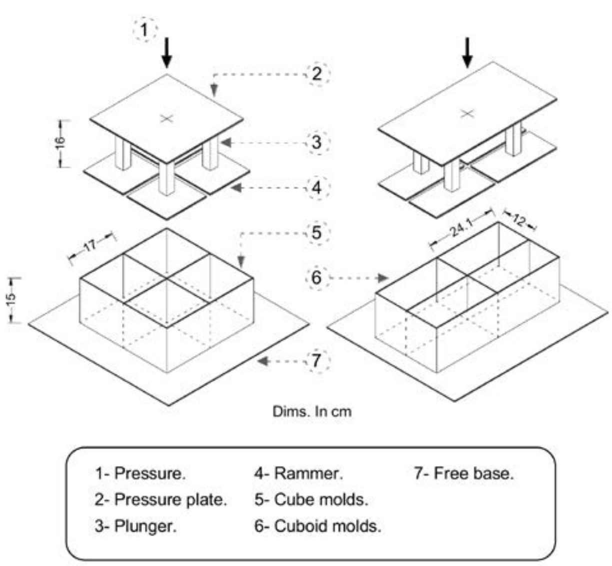

Fig. 1 Engineering drawing of the cube and cuboid molds

Fig. 2 Photographs view of the cube and cuboid molds

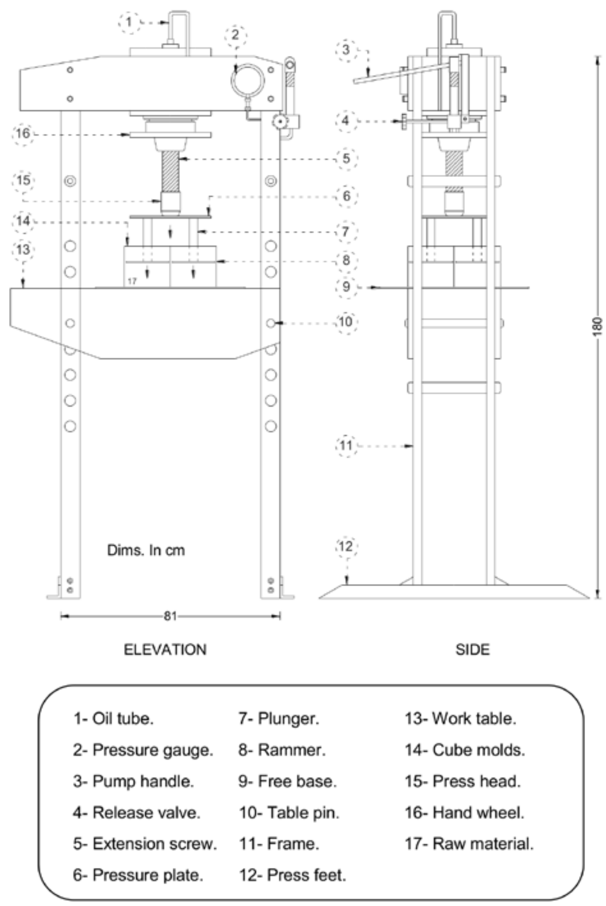

Fig. 3 Schematic diagram of the hydraulic press with cube molds

straw of about 10.32, 13.41 and 16.58%, w.b.

Measurements

Moisture content of rice straw

The moisture content of rice straw was determined before densification process, using the oven method (at about 70°C to constant mass) according to ASAE standard, 1998.

Bulk density of feed blocks:

Bulk density is an indicator of savings in storage area, transportation space and cost of blocks. The bulk density of the compacted blocks was calculated with the sample mass and the measured volume in each treatment. The volume was determined by the cross sectional area and thickness variables of the blocks. The thickness of blocks, which varies during post-compression recovery, after 24 h was used to calculate the stable density of blocks according to Singh, *et al*., 2005 and Jha *et al*., 2008. The bulk density of the un-compacted samples (initial bulk density) of the chopped rice straw was evaluated at different levels of molasses content and moisture content. The average determined initial bulk density was about 173.01±1.384 kg/m^3. The un-compacted density was used for the comparisons with the bulk density of the corresponding compacted blocks.

Densification degree of feed blocks

Degree of densification is defined as percent increase in density of blocks due to compressing. Degree of densification represented ability of material to get binding effect, that degree was determined according to Ghorpade and Moule, 2006, using equation, 1.

Densification degree = {(Bulk density of feed block - Initial bulk density) / Initial bulk density} × 100, % ....(1)

Resiliency of feed blocks

After the block was removed from the compaction mold, the resiliency (length recovery) was measured with time varying from 5 min to 24 h. Resiliency indicates the elastic property of the material. It was determined as the ratio of increase in thickness to the initial thickness of the block (equation, 2). The thickness of the blocks, which varied with time, was measured initially at 5 min intervals up to 30 min and then after 24 h according to the method of Singh, *et al*., 2005 and Jha *et al*., 2008.

Resiliency = {(Thickness of stabilized block - Initial thickness of block) / Initail thickness of block} × 100, % ....(2)

Durability of feed blocks

Durability is the most important aspect of block quality. It means the ability of blocks to withstand the rigors of handling and delivery without breaking-up (Payne, 2006). The durability of blocks was determined according to ASAE standard, 1998. The tumbling device was used for testing purpose under 40 rpm for three minutes and after 24 h from forming blocks. The durability index was calculated by using the following equation:

Durability index = (Mass of sound block after tumbling) / Mass of block before tumbling) × 100, % ......(3)

Stiffness of feed blocks

Stiffness reflects the degree of binding. It was measured as the maximum force (Newton) recorded while the dry feed block was broken by a portable stiffness tester (Model, 174866-Kiyo-Seisakusho, L.T.D, Japan).

Productivity

The productivity of formation equipments was determined with the average mass (or number) of the feed blocks and the calculated densification time.

Cost

Fixed costs

a- Depreciation: Declining balance method was used to determine the depreciation (Hunt, 1983). In this method the depreciation value is different for every year of the machines life (hydraulic press and molds combination).

b- Interest on investment, shelter taxes and insurance: They were estimated as 17.5% of the remaining value.

Variable costs

Variable costs include the cost of repairs and maintenance, hydraulic oil and labor. For machinery, repairs and maintenance is about 5.77% as a percent of purchase price.

Machinery unit cost

It calculated by using the following formula:

Machinery unit cost = (Total cost / Productivity), LE / ton ....(4)

Results and Discussion

Bulk Density of Feed Blocks

Fig. 4 illustrates the effect of compression pressure, molasses content and rice straw moisture content for both cube and cuboid molds on bulk density of feed blocks. For cube mold, it can be observed that, the increase in compression pressure from 24.52 to 53.94 MPa leads to increase the blocks bulk density from 260.48 to 346.67, from 315.24 to 401.56 and from 384.48 to 477.46 kg/m^3 with molasses content of 4% and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase in compression pressure increased the blocks bulk density of cuboid mold from 254.03 to 320.23, from 298.79 to 395.11 and from 382.45 to 470.01 kg/m^3 at the same above mentioned conditions, respectively. The same trend was obtained with other molasses content for cube and cuboid molds. In the same manner, for cube mold, the increase of rice straw moisture content from 10.32 to 16.58% leads to increase the blocks bulk density from 260.48 to 384.48, from 281.86 to 433.76, from 302.58 to 454.18 and from 346.67 to 477.46 kg/m^3 with molasses content of 4% and compression pressure of 24.52, 34.32, 44.13 and 53.94 MPa, respectively. Also, the same increase of rice straw moisture content increased the blocks bulk density of cuboid mold from 254.03 to 382.45, from 267.51 to 405.64, from 298.13 to 447.73 and from 320.23 to 470.01 kg/m^3 at the same above mentioned conditions, respectively. The same results were obtained with other molasses content for cube and cuboid molds. On the other hand, for cube mold, the increase of molasses content from 4 to 10% leads to increase the blocks bulk density from 260.48 to 373.52, from 315.24 to 440.42 and from 384.48 to 524.23 kg/m^3 with compression pressure of 24.52 MPa and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase of molasses content increased the blocks bulk density of cuboid mold from 254.03 to 371.51, from 298.79 to 426.46 and from 382.45 to 508.88 kg/m^3 at the same above mentioned conditions, respectively. The same trend was obtained with other compression pressure for cube and cuboid molds. Briefly, it was noticed that the highest values of blocks bulk density of cube and cuboid molds were found to be 659.87 and 632.04 kg/m^3, respectively, at compression pressure of 53.94 MPa, molasses content of 10% and rice straw moisture content of 16.58%. Comparing the highest values of blocks bulk density for cube and cuboid molds, the results showed that, the value of block bulk density for cube mold was higher than that of cuboid mold by 4.4% at the same above mentioned conditions. In the opposite side, the lowest values of blocks bulk density of cube and cuboid molds were reached 260.48 and 254.03 kg/m^3, respectively, at compression pressure of 24.52 MPa, molasses content of 4% and rice straw moisture content of 10.32%. Comparing the lowest values of blocks bulk density for cube and cuboid molds, the data showed that, the value of block bulk density for cube mold was higher than that of cuboid mold by 2.5% at the same above mentioned conditions. Eventually, for both cube and cuboid molds, the increase in compressibility of rice straw with increasing molasses and moisture contents has been attributed to the increase in cohesion and adhesion force between the compressed material due to increased formation of liquid bridges between the particles, also rice straw become softer and therefore deform more when they adsorb moisture. In addition, more of the void space is expelled when pressure is increased, hence the increase in compressibility. The results indicated that the cube mold was found to be the most appropriate for high stability compressed blocks. This may be due to pressure distribution of cube mould on cross-sectional area was better than cuboid mould.

Densification Degree of Feed Blocks

The influences of compression pressure, molasses content and rice straw moisture content for both cube and cuboid molds on densification degree of feed blocks are shown in **Fig. 5**. General trend was observed where the blocks densification degree increased by increasing the compression pressure at constant molasses content and rice straw moisture content. For cube mold, it can be observed that, the increase of compression pressure from 24.52

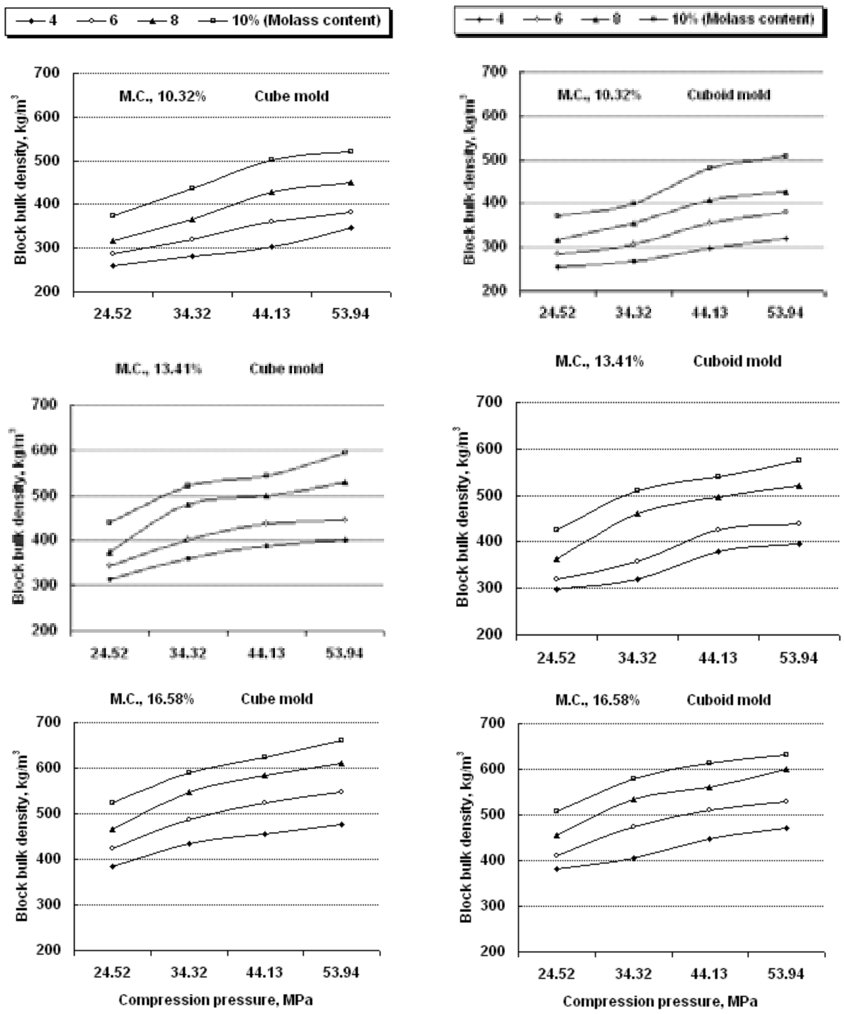

Fig. 4 Effect of compression pressure, molasses content and rice straw moisture content on block bulk density for cube and cuboid molds.

to 53.94 MPa leads to increase the blocks densification degree from 50.56 to 100.38, from 82.21 to 132.10 and from 122.23 to 175.97% with molasses content of 4% and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase of compression pressure increased the blocks densification degree of cuboid mold from 46.83 to 85.09, from 72.70 to 128.37 and from 121.06 to 171.67% at the same above mentioned conditions, respectively. The same trend was obtained with other molasses content for cube and cuboid molds. For cube mold, the increase of rice straw moisture content from 10.32 to 16.58% leads to increase the blocks densification degree from 50.56 to 122.23, from 62.92 to 150.71, from 74.89 to 162.52 and from 100.38 to 175.97% with molasses content of 4% and compression pressure of 24.52, 34.32, 44.13 and 53.94 MPa, respectively. Also, the same increase of rice straw moisture content increased the blocks densification degree of cuboid mold from 46.83 to 121.06, from 54.62 to 134.46, from 72.32 to 158.79 and from 85.09 to 171.67% at the same above mentioned conditions, respectively. The same results were obtained with other molasses content for cube and cuboid molds. In the same manner, for cube mold, the increase of molasses content from 4 to 10% leads to increase the blocks densification degree from 50.56 to 115.90, from 82.21 to 154.56 and from 122.23 to 203.01% with compression pressure of 24.52 MPa and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase of molasses content increased the blocks densification degree of cuboid mold from 46.83 to 114.73, from 72.70 to 146.49 and from 121.06 to 194.13% at the same above mentioned conditions, respectively. In general, it was noticed that the highest values of blocks densification degree of cube and cuboid molds were found to be 281.41 and 265.32%, respectively, at compression pressure of 53.94 MPa, molasses content of 10% and rice straw moisture content of 16.58%. Comparing the highest values of blocks densification degree for cube and cuboid molds, the results showed that, the value of block densification degree for cube mold was higher than that of cuboid mold by 6.1% at the same above mentioned conditions. On the other hand, the lowest values of blocks densification degree of cube and cuboid molds were reached 50.56 and 46.83%, respectively, at compression pressure of 24.52 MPa, molasses content of 4% and rice straw moisture content of 10.32%. Comparing the lowest values of blocks densification degree for cube and cuboid molds, the data showed that, the value of block densification degree for cube mold was higher than that of cuboid mold by 8% at the same above mentioned conditions.

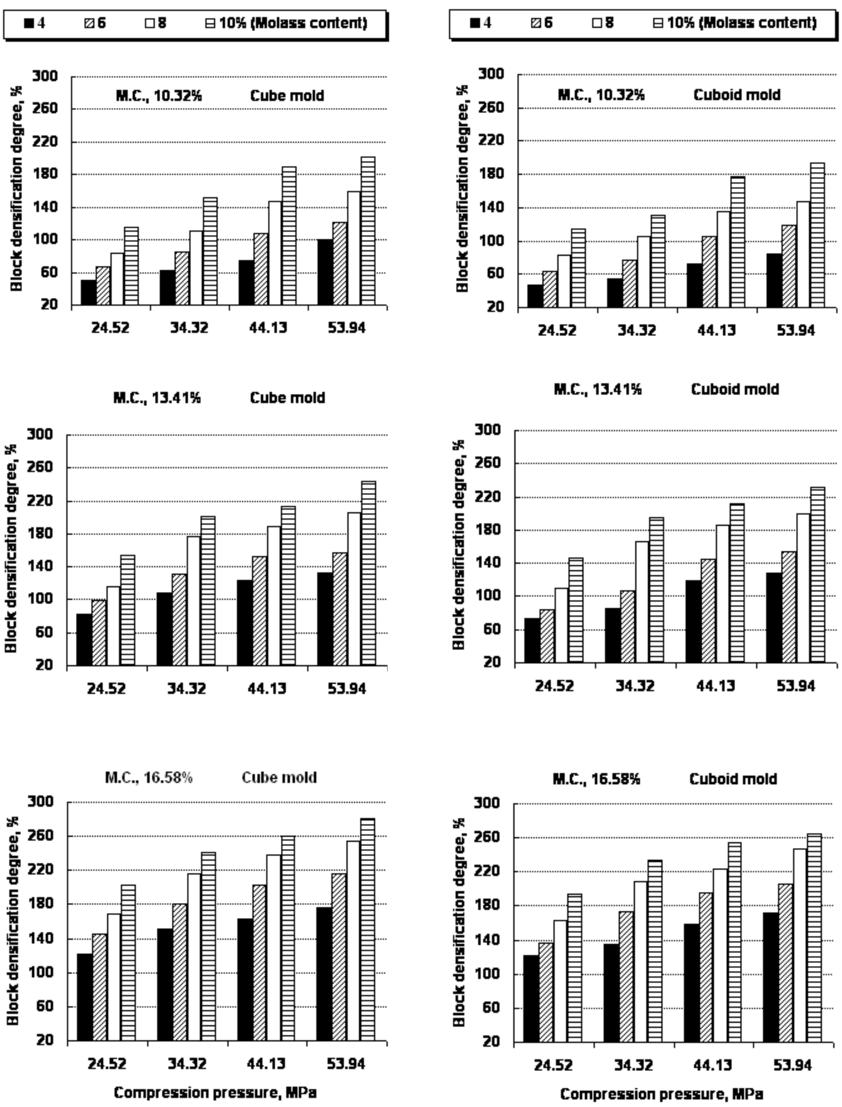

Fig. 5 Effect of compression pressure, molasses content and rice straw moisture content on block densification degree for cube and cuboid molds

Resiliency of Feed Blocks

Data presented in **Fig. 6** illustrates the impact of compression pressure, molasses content and rice straw moisture content for both cube and cuboid molds on feed blocks resiliency. For cube mold, it can be observed that, the increase of compression pressure from 24.52 to 53.94 MPa lead to decrease the blocks resiliency from 25.35 to 21.41, from 23.88 to 19.94 and from 19.45 to 15.48% with molasses content of 4% and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase of compression pressure decreased the blocks resiliency of cuboid mold from 28.04 to 23.53, from 26.12 to 22.26 and from 22.20 to 17.34% at the same above mentioned conditions, respectively. The same trend was obtained with other molasses content for cube and cuboid molds. In the same manner, for cube mold, the increase of rice straw moisture content from 10.32 to 16.58% leads to decrease the blocks resiliency from 25.35 to 19.45, from 23.65 to 17.72, from 22.75 to 16.82 and from 21.41 to 15.48% with molasses content of 4% and compression pressure of 24.52, 34.32, 44.13 and 53.94MPa, respectively. Also, the same increase of rice straw moisture content decreased the blocks resiliency of cuboid mold from 28.04 to 22.20, from 26.39 to 19.79, from 24.98 to 18.89 and from 23.53 to 17.34% at the same above mentioned conditions, respectively. The same results were obtained with other molasses content for cube and cuboid molds. On the other hand, for cube mold, the increase of molasses content from 4 to 10% leads to decrease the blocks resiliency from 25.35 to 19.57, from 23.88 to 18.17 and from 19.45 to 13.64% with compression pressure of 24.52 MPa and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase of molasses content decreased the blocks resiliency of cuboid mold from 28.04 to 21.86, from 26.12 to 19.73 and from 22.20 to 16.09% at the same above mentioned conditions, respectively. The same trend was obtained with other compression pressure for cube and cuboid molds. Generally, it was noticed that the lowest values of blocks resiliency of cube and cuboid molds were found to be 8.35 and 10.03%, respectively, at compression pressure of 53.94 MPa, molasses content of 10% and rice straw moisture content of 16.58%. Comparing the lowest values of blocks resiliency for cube and cuboid molds, the results showed that, the value of block resiliency for cube mold was less than that of cuboid mold by 16.7% at the same above mentioned conditions. In the opposite side, the highest values of blocks resiliency of cube and cuboid molds were reached 25.35 and 28.04%, respectively, at compression pressure of 24.52 MPa, molasses content of 4% and rice straw moisture content of 10.32%. Comparing the highest values of blocks resiliency for cube and cuboid molds, the data showed that, the value of block resiliency for cube mold was less than that of cuboid mold by 9.6% at the same above mentioned conditions.

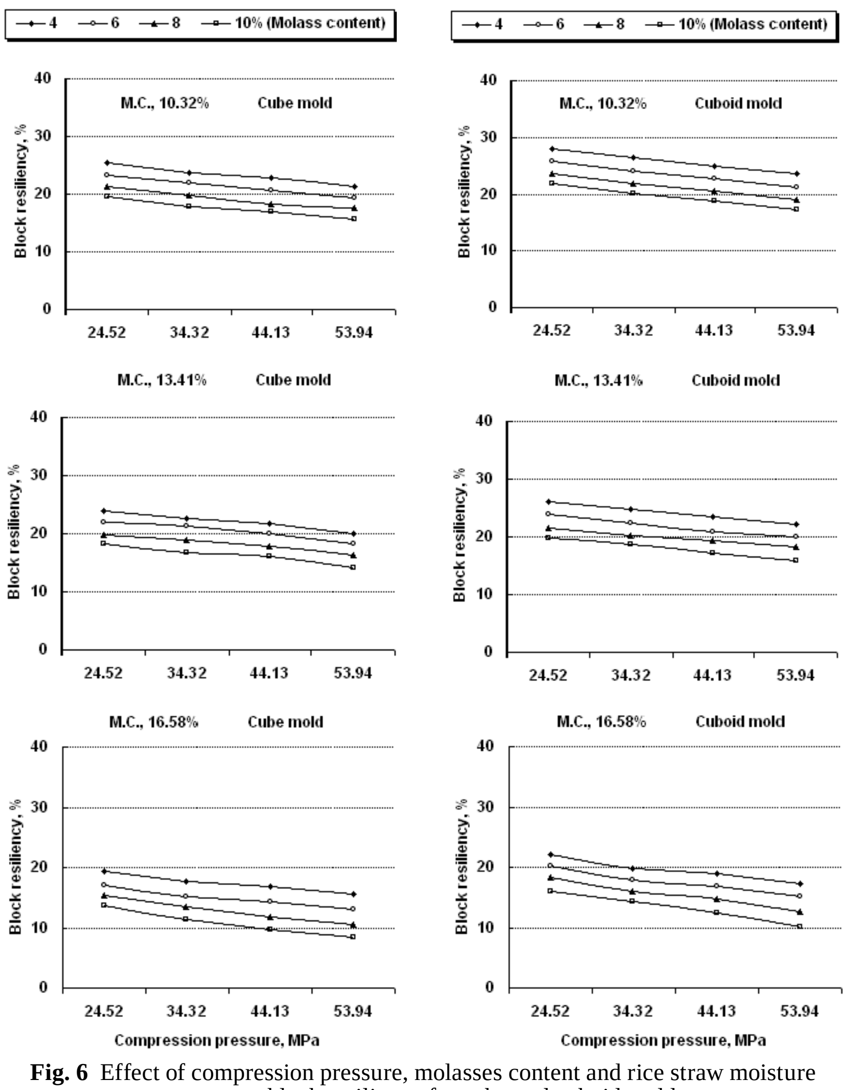

Fig. 6 Effect of compression pressure, molasses content and rice straw moisture content on block resiliency for cube and cuboid molds

Durability of Feed Blocks

Fig. 7 explains the blocks durability as affected by compression pressure for both cube and cuboid molds at different levels of molasses content and moisture content of rice straw. For cube mold, it is conceivable that, the increase of compression pressure from 24.52 to 53.94 MPa tends to increase the blocks durability from 93.02 to 96.68, from

92.07 to 94.85 and from 89.73 to 93.28% with molasses content of 4% and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase of compression pressure increased the blocks durability of cuboid mold from 91.03 to 93.98, from 88.82 to 92.87 and from 87.74 to 90.72% at the same above mentioned conditions, respectively. The same trend was obtained with other molasses content for cube and cuboid molds. From the previous data it is evident that, for cube mold, the increase of rice straw moisture content from 10.32 to 16.58% tends to decrease the blocks durability from 93.02 to 89.73, from 94.08 to 90.86, from 94.99 to 91.81 and from 96.68 to 93.28% with molasses content of 4% and compression pressure of 24.52, 34.32, 44.13 and 53.94 MPa, respectively. Also, the same increase of rice straw moisture content decreased the blocks durability of cuboid mold from 91.03 to 87.74, from 92.08 to 88.34, from 92.99 to 89.23 and from 93.98 to 90.72% at the same above mentioned conditions, respectively. The same results were obtained with other molasses content for cube and cuboid molds. Moreover, for cube mold, the increase of molasses content from 4 to 10% tends to increase the blocks durability from 93.02 to 95.79, from 92.07 to 94.59 and from 89.73 to 92.84% with compression pressure of 24.52 MPa and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase of molasses content increased the blocks durability of cuboid mold from 91.03 to 93.79, from 88.82 to 92.61 and from 87.74 to 90.19% at the same above mentioned conditions, respectively. The same trend was obtained with other compression pressure for cube and cuboid molds. Briefly, it was observed that, the highest values of blocks durability of cube and cuboid molds were found to be 99.27 and 96.92%, respectively, at compression pressure of 53.94 MPa, molasses content of 10% and rice straw moisture content of 10.32%. Comparing the highest values of blocks durability for cube and cuboid molds, the results showed that, the value of block durability for cube mold was higher than that of cuboid mold by 2.4% at the same above mentioned conditions. In the opposite side, the lowest values of blocks durability of cube and cuboid molds were reached 89.73 and 87.74, respectively, at compression pressure of 24.52 MPa, molasses content of 4% and rice straw moisture content of 16.58%. Comparing the lowest values of blocks durability for cube and cuboid molds, the data showed that, the value of block durability for cube mold was higher than that of cuboid mold by 2.3% at the same above mentioned conditions.

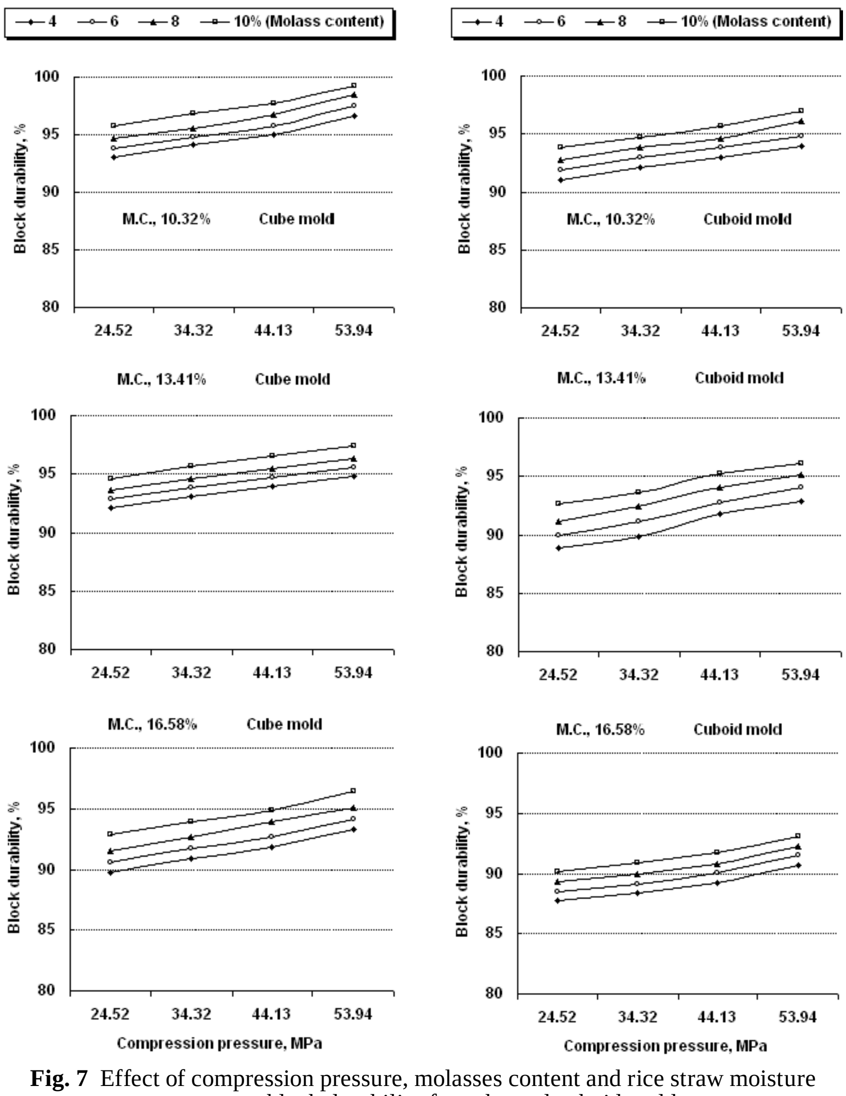

Fig. 7 Effect of compression pressure, molasses content and rice straw moisture content on block durability for cube and cuboid molds

Stiffness of Feed Blocks

Data presented in **Fig. 8** illustrates the effect of compression pressure, molasses content and rice straw moisture content for both cube and cuboid molds on feed blocks stiffness. For cube mold, it can be observed that, the increase of compression pressure from 24.52 to 53.94 MPa tends to increase the blocks stiffness from 371.24 to 380.32, from 365.42 to 374.79 and from 358.46 to 367.92 N with molasses content of 4% and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase of compression pressure increased the blocks stiffness of cuboid mold from 367.41 to 375.63, from 360.93 to 368.45 and from 354.85 to 362.96 N at the same above mentioned conditions, respectively. The same trend was obtained with other molasses content for cube and cuboid molds. From the previous data it is evident that, for cube mold, the increase of rice straw moisture content from 10.32 to 16.58% tends to decrease the blocks stiffness from 371.24 to 358.46, from 374.19 to 361.62, from 377.81 to 364.75 and from 380.32 to 367.92 N with molasses content of 4% and compression pressure of 24.52, 34.32, 44.13 and 53.94 MPa, respectively. Also, the same increase of rice straw moisture content decreased the blocks stiffness of cuboid mold from 367.41 to 354.85, from 369.85 to 357.64, from 372.34 to 359.63 and from 375.63 to 362.96 N at the same above mentioned conditions, respectively. The same results were obtained with other molasses content for cube and cuboid molds. On the other hand, for cube mold, the increase of molasses content from 4 to 10% tends to increase the blocks stiffness from 371.24 to 375.95, from 365.42 to 369.94 and from 358.46 to 363.70 N with compression pressure of 24.52 MPa and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase of molasses content increased the blocks stiffness of cuboid mold from 367.41 to 372.35, from 360.93 to 365.45 and from 354.85 to 359.86N at the same above mentioned conditions, respectively. The same trend was obtained with other compression pressure for cube and cuboid molds. Generally, it was observed that, the highest values of blocks stiffness of cube and cuboid molds were found to be 385.22 and 380.86 N, respectively, at compression pressure of 53.94 MPa, molasses content of 10% and rice straw moisture content of 10.32%. Comparing the highest values of blocks stiffness for cube and cuboid molds, the results showed that, the value of block stiffness for cube mold was higher than that of cuboid mold by 1.1% at the same above mentioned conditions. In the opposite side, the lowest values of blocks stiffness of cube and cuboid molds were reached 358.46 and 354.85 N, respectively, at compression pressure of 24.52 MPa, molasses content of 4% and rice straw moisture content of 16.58%. Comparing the lowest values of blocks stiffness for cube and cuboid molds, the data showed that, the value of block stiffness for cube mold was higher than that of cuboid mold by 1% at the same above mentioned conditions.

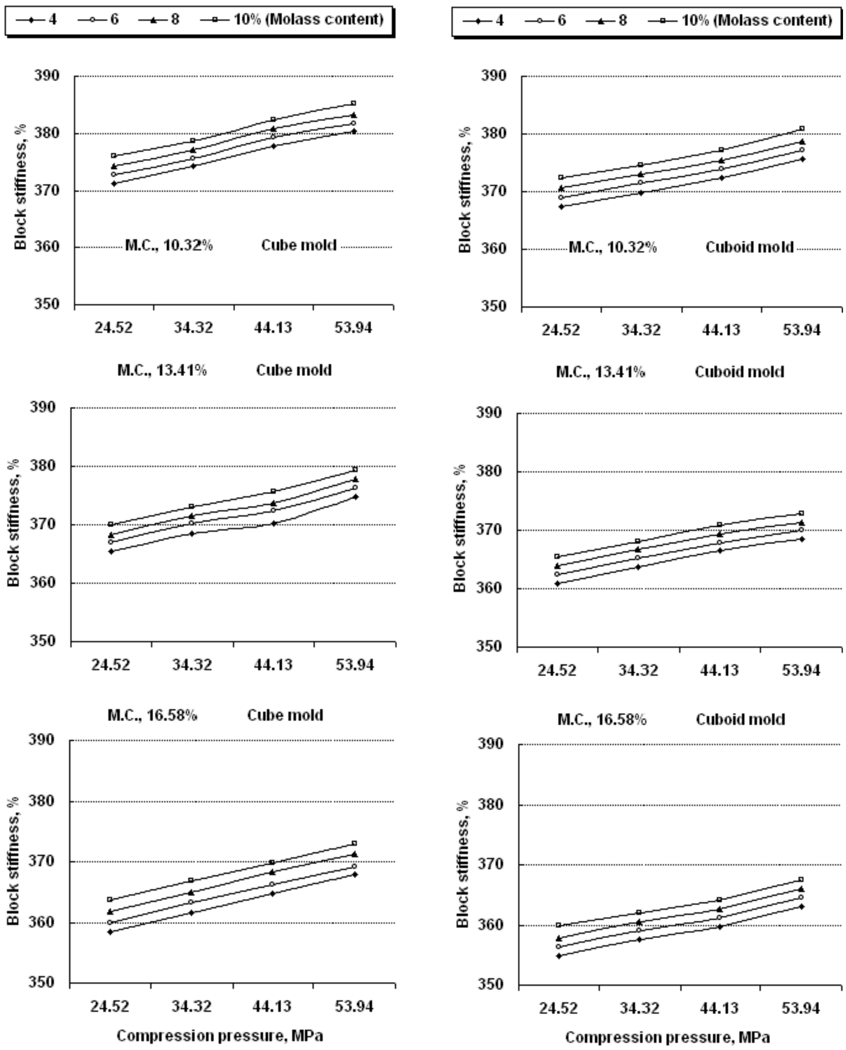

Fig. 8 Effect of compression pressure, molasses content and rice straw moisture content on block stiffness for cube and cuboid molds

Productivity and Machinery Unit Cost

For all operating conditions, the time to produce four blocks was about 0.0666h at one time, and the average mass of the feed block was about 0.75 kg. So, the average productivity of the investigated feed block formation equipment was 60 feed block/h (45 kg/h). The feed blocks production cost using the hydraulic press with the mold combination are listed in **Table 1**. As shown in the **Table**, the estimated unit cost of the feed blocks using the formation equipment was 8.144 LE/

h, whilst the production cost per kg of raw material was 0.18097 LE.

Conclusions

The following conclusions were drawn from this study:

- A combination of compression pressure of 53.94 MPa, molasses content of 10% and 16.58% moisture content of rice straw was optimum. Under the optimum settings of the variables, for cube and cuboid molds, the feed blocks produced had a bulk density of 659.87 and 632.04 kg/m^3, densification degree of 281.41 and 265.32% and resiliency of 8.35 and 10.03%, respectively.
- For cube and cuboid molds, the highest values of blocks durability were found to be 99.27 and 96.92%, respectively, at 10.32% moisture content of rice straw, 53.94 MPa compression pressure and 10% molasses content, and also the highest values of blocks stiffness were 385.22 and 380.86 N, respectively at the same previous conditions.
- Comparing between the two geometrical shapes of mold, the cube mold was found to be the most appropriate for high stability compressed blocks.
- The average productivity of the investigated feed block formation equipments was 60 feed block/h, while the machinery unit cost was about 8.144 LE/h.

Table 1 Cost estimation for the hydraulic press with molds combination

Assumptions:	
Price of the hydraulic press and molds combination, LE*	4000
Time to produce four blocks, h	0.0666
Number of the feed blocks per hour	60
Average mass of feed block, kg	0.75
Operation hours, h/Yr	2000
Total fixed cost, LE/h	0.5079
Depreciation cost, LE/h	0.255
Interest, taxes, insurance and shelter cost, LE/h	0.2529
Total Variable cost, LE/h	7.6365
Repair and maintenance cost, LE/h	0.0115
hydraulic oil cost, LE/h	0.125
Labor cost, LE/h	7.5
Machinery unit cost:	
LE/h	8.144
LE/kg	0.18097
LE/ton	180.97

* One Egyptian Pound (LE) = 7.63 American dollar ($), 2015.

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Development of a Sorting System for Fruits and Vegetables Based on Acoustic Resonance Technique

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INDIA

Abstract

Sorting of fresh fruits and vegetables is essential in order to minimize post-harvest losses. In practice, it is carried out by visual inspection or destructive testing procedures; both of which are labour and time intensive processes. Hence, in recent years, numerous research works have focussed on developing rapid, accurate and non-destructive techniques for such applications. The present work was aimed to develop a sorting system prototype based on non-destructive acoustic resonance technique. The developed system can sort fruits and vegetables into different classes, based on acoustic responses. The performance of the system was evaluated by conducting studies to determine the maturity stages of sapota and to check the presence of internal defects in brinjal. Results were in good agreement (overall classification efficiency of 89% and 87% respectively) with those obtained by conventional destructive testing procedures.

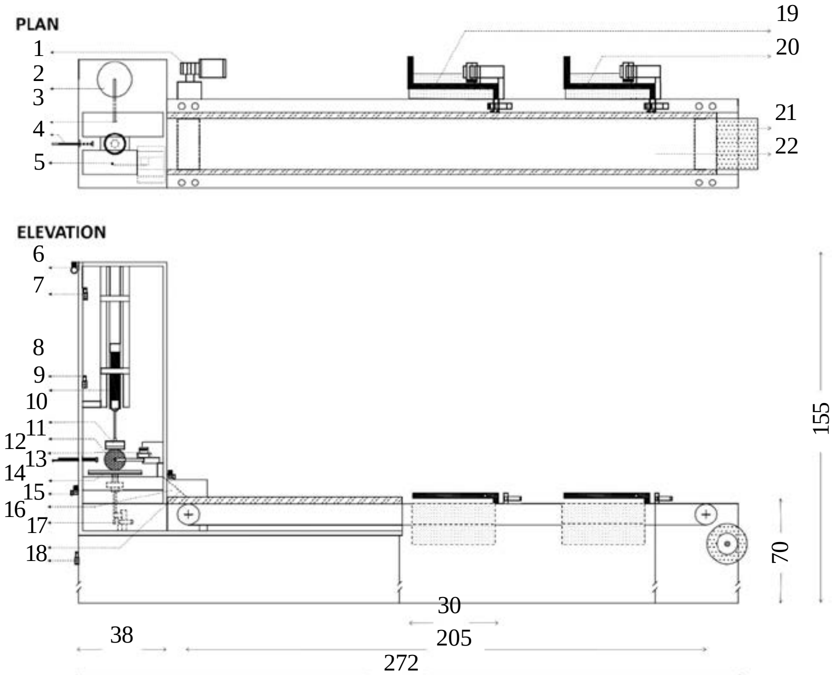
Keywords: Acoustic resonance; non-destructive test; internal defect; fruit firmness

Introduction

Fruit quality is dependent on both internal (firmness, percent soluble solids, percent acid content and presence or absence of internal defects) and external (colour, shape, size and external defects) attributes. These factors decide the overall market acceptability and product value. Sorting is a process that can categorize agricultural produce into different classes based on size, shape, texture and colour. To overcome the problems encountered with destructive testing procedures, several non-destructive methods have been developed by several researchers over the last three decades. These methods are based on the detection of various physical characteristics which correlate with certain quality aspects of the produce. In most developing countries however, sorting is a slow and laborious process that is often done by visual inspection; an approach that is highly prone to errors and biased decisions. There is a need for cost effective mechanical sorting systems that can provide rapid and accurate results in on-line applications.

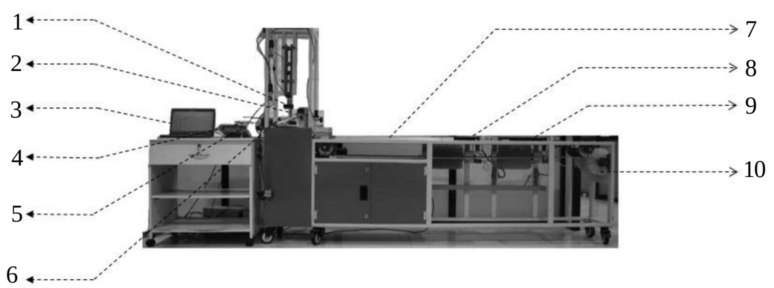
Acoustic resonance technique is a non-destructive method which takes its concept from indigenous knowledge. Just as how the quality of coconut or watermelon is judged from the sound produced on tapping, this technique can predict the quality of fruits and vegetable based on the acoustic responses created on impaction, once the frequency spectrum is analysed. Acoustic quality evaluation has a wide range of scientific and engineering applications including: detection of delaminations in concrete slabs (Yu and Haupt, 2010), detection of structural defects in metals, alloys and ceramics (Klepka *et al*., 2012) and quality inspection of timber (Paradis *et al*., 2013).

The effectiveness of acoustic resonance technique has been investigated for a range of agricultural products such as: separation of infected wheat kernels from healthy ones (Pearson *et al*., 2007) and pistachio nuts from kernels (Haff *et al*., 2007), detection of hollow potato tubers (Elbatawi, 2008), sorting of pinto beans (Pan *et al*., 2010), intelligent classification of seeds (Gasso-Tortajada *et al*., 2010), separation of potato and clod (Hosainpour *et al*., 2011), separation of gelled and non-gelled preserved eggs (Chen *et al*., 2011), sorting of walnuts (Khalesi *et al*., 2012) and detection of cracks in egg shell (Sun *et al*., 2013). The objective of the present work was to develop a non-destructive sorting system based on acoustic resonance technique for fruits and vegetables. The developed prototype will be able to classify fruits based on maturity stages and can also detect the presence of internal defects in fruits and vegetables.



All dimensions are in cm; (1) 0.5 hp motor for belt conveyor, (2) mic holder, (3) microphone, (4) single acting cylinder for ejection system, (5) impacting device, (6) air regulator for sample holder, (7) solenoid valve for sample holder, (8) solenoid valve for ejection system, (9) single acting cylinder for sample holder, (10) sample holder, (11) test sample, (12) semi-rotary drive, (13) fruit bed, (14) air regulator for ejection system, (15) supporting plate, (16) proximity sensor, (17) sliding plate, (18) solenoid valve for impacting device, (19) flapper gate and components for Grade A, (20) flapper gate and components for Grade B, (21) brush roller and (22) belt conveyor.

Fig. 1 Schematic Diagram of Sorting System based on Acoustic Resonance Technique



(1) sample holder, (2) sound acquisition system, (3) personal computer for control and database interpretations, (4) ejection system for dispense the fruit to conveying unit, (5) signal processing unit, (6) impacting device, (7) flapper gate for Grade A, (8) flapper gate for Grade B, (9) single acting cylinder for sample holder and (10) brush roller

Fig. 2 Prototype Sorting System based on Acoustic Resonance Technique

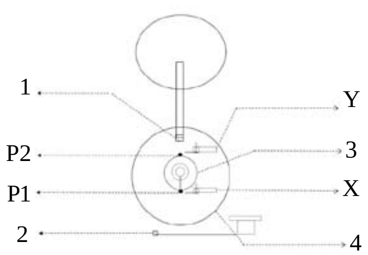
Materials and Methods

The plan and elevation views of the sorting system based on acoustic resonance technique designed with Auto CAD (Auto CAD, 2012) are presented in **Fig. 1**. The prototype consists of a sample holder cum impacting device, sound acquisition system, signal processing unit, classification system and personal computer for process control and database interpretations (**Fig. 2**). The following sections describe the methodology adopted and the role and specifications for each component.

Sample Holder cum Impacting Device

Creation of an impact to the sample is the foremost step in acoustic resonance technique. The sample must be impacted without free vibration; hence needs to be held in a rigid position during the impact period. Sample holder unit consists of fruit bed and single acting cylinder (Model: SC 514, M/s Janatics India

Pvt. Ltd., India). Sample is placed over the fruit bed which has a 15 cm diameter mild steel plate covered with 2.5 cm thick polyurethane foam. Dominant frequency values obtained upon impacting at two equatorially opposite positions were check for consistency. The impacting device consists of semi-rotary drive (Model: DSR 10-180 P, M/s Festo, India) and rectangular plate (15 × 2.5 cm), at the end of which is a provision to fix different impact materials. Based on the swivel angle fixed in the semi-rotary drive, the amount of force exerted on the sample can be varied. The fruit bed is rotated using a 12 Volt DC motor to 1800 to allow the sample to get the second impact in the opposite position. Two proximate sensors (Model: ID 18-3008, M/s Janatics India Pvt. Ltd., India) X and Y are fixed at opposite positions around the rotating plate (**Fig. 3**). The first impact was given when the fruit is at point P1 (while at position A). Then the plate rotates by an angle of 180° (point P2 now shifts to position B), activating the proximate sensor Y and thereby stopping the motor. At this position, the second impact is given at point P2. Once the sample gets two impacts, the fruit bed comes to the initial position A. The single acting cylinder that is fixed on the rigid main frame facilitates in holding the sample. At the end of pneumatic



(1) microphone, (2) impacting device, (3) sample to be tested, (4) rotating plate, (P1) impacting point P1 at position A, (P2) impacting point P2 at position B, (X) proximate sensor X and (Y) proximate sensor Y

Fig. 3 Plan View of Rotating Plate and other Components

cylinder, a 7.5 cm round plate with 5 cm thick polyurethane foam covering was provided to avoid any impact injury to the sample. Solenoid valve (Model: DS2 5/2, M/s Janatics India Pvt. Ltd., India) was used to control the movements of the single acting cylinder and semi rotary drive with the help of air regulators (Model: R3164, M/s Janatics India Pvt. Ltd., India).

Sound Acquisition System

Upon impact, the sound transmitted is acquired without free noise interferences. A pre-polarized free-field microphone (Model: 4189 B&K, 46 AE, sensitivity: 50 $mVPa^{-1}$, M/s m+p international, Germany) was used to capture the resonant sound when the impact was created. It was positioned at a distance of 10 mm from the point in the sample that is just opposite to the point of impact (**Fig. 3**). Once the resonant sound was captured, it was converted to electrical signal by means of a wire coil-magnet setup; based on the principle of electromagnetism. For rigid positioning, the microphone (8 cm × 1.32 cm) is fixed on a stand using rubber cork gripping.

Signal Processing Unit

Signal processing by Fast Fourier Transformation (FFT) was essential to convert the sound signal into frequency spectra with hanning window configuration. Dynamic signal analyzer (Model: VP4-SO2010, V4.1 B3096 CD8.06.02, M/s m+p international, Germany) was used for signal processing by connecting the microphone output to it. In order to acquire information from the frequency spectrum, windows-based dynamic signal acquisition and analysis software (SO analyzer software 8.023) was used for data acquisition. Sampling at 40 kHz for 4096 points resulted in a FFT frequency resolution of 9.77 Hz. The SO analyser software plotted ‘time vs. intensity’ and ‘amplitude vs. frequency’ graphs at the end of each test.

Classification System

The classification system consists of conveyor belt and two ejection systems; first of which is used to eject the fruit from the sample holder (marked as 4 in **Fig. 2**). The first ejection system consist of a single acting cylinder (Model: A510162, M/s Janatics India Pvt. Ltd., India) with a supportive plate (6 × 3 cm, covered with polyurethane foam) and is operated after acquiring the acoustic response of the impacts. For easier conveying, a sliding plate (with 60° slope) was used between the fruit bed and conveying system. In order to prevent the fruit from rolling out of the the conveying system, two supporting plates (15 × 10 × 0.2 cm) were fixed at 0.5 cm from the belt conveyor (30 cm width) on both sides. The spacing between the pulleys was 205 cm and the belt conveyor was set at a forward speed of 30 cm/ s when operated using a 0.5 hp motor.

The second ejection system subcomprises of two flapper gate units (marked as 8 and 9 in **Fig. 2**) that direct the sample out of the conveying system as grade A or grade B. Two proximity sensors were used at each flapper gate to perform ‘open’ (to restrict the sample from continuing to move on the conveyor) and ‘close’ (to direct the sample to the particular grade) functions. The first and second flapper gate guide the sample to grade A and grade B respectively. Samples that remain on the conveyor belt would be collected at the end of the conveyor as grade C. To ensure that the sample does not suffer any damage during ejection, brush rollers (30 cm length and 15 cm diameter) were fixed between the conveying system and collection bins (for all three grades).

Personal Computer for Control and Database

In the prototype Programmable

Logic Control (PLC) and Human Machine Interface (HMI) were used for automation. PLC is used for controlling operations such as input reception from sensors, setting limit for switches and other functions (to control movement of motors, impact device, conveyor belt and ejection system). HMI is user-friendly and is essential to exchange information between the system and the user. It allows the user to control the system with 'start', 'stop' and 'reset' options, time settings for gate openings (**Fig. 4**). The time given for each operation is optimized based on preliminary trial and error experiments.

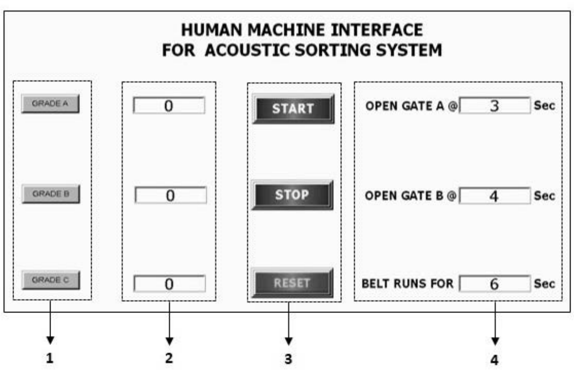
To summarise the test procedure; once the sample is placed in the fruit bed, test commences by clicking 'start' in the HMI screen. The fruit is held rigidly for two impacts and acoustic responses are recorded and sent to digital signal analyser for analysis. The system waits for a response from the user. The frequency spectrum obtained is exported to the MS Excel (**Fig. 5**) and the program is designed in such a way that it directly shows the dominant frequency and the particular gate to be activated. This is based on experimental results of dominant frequency values obtained for a minimum of 100 samples (in this case, each fruit maturity class or the presence or absence of internal defects) and then activates a particular gate to be 'open' (**Fig. 4**). Once the gate is activated, the sample holder releases the fruit and ejects it to conveying system. The fruit will then be guided to the appropriate grade bin based on selections made in the HMI.

Applications Using the Developed Acoustic Resonance Technique Based Prototype

Acoustic resonance technique is a promising rapid non-destructive approach that feasible for real time food quality detection applications. Many researchers have successfully used this technique to determine the firmness of apple (Mendoza *et al.*, 2012), apricot (Petrisor *et al.*, 2010), mango (Padda *et al.*, 2011), melon (Taniwaki *et al.*, 2010) and watermelon (Zhang *et al.*, 2010). This method also has been successfully used to detect translucent fresh disorder and yellow gummy latex in mangosteen (Jatringam *et al.*, 2013), to detect the egg albumen quality (Tona *et al.*, 2013). Data analysis and interpretation are simple and the system is compact as compared to other non-destructive techniques. The present prototype was used to classify sapota into three grades based on maturity stages (as mature fruit, semi-ripe and ripe fruits) and brinjal into two grades based on the internal defects (as present or absent).

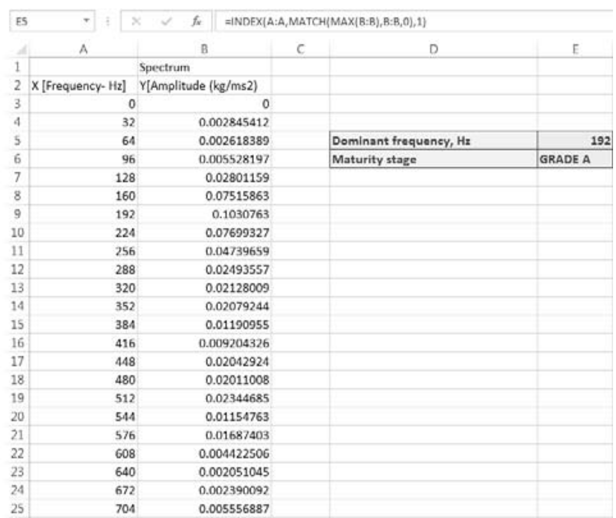
Determination of Maturity Stage of Sapota

The maturity stage of sapota can be determined based on visual inspection of fruit size, scurf content and skin colour or using results of destructive tests such as puncture test, pH, total soluble solids and titratable acidity measurements. In the present study, sapota (cultivar: cricket ball) were categorized into different maturity stages based on the dominant frequency values obtained. Experimental work revealed that dominant frequency is a direct measure of fruit firmness. The dominant frequency for different maturity stages was found to be 800-864 Hz (mature), 352-416 Hz (semi-ripe) and 174-232 Hz (ripe). Significant decrease in dominant frequency values were observed with ripening. Similar trends were noticed by several researchers on melon (Baki *et al.*, 2010), peach (Gomez *et al.*, 2005), mandarin (Wang *et al.*, 2006), mango (Raju *et al.*, 2007)



(1) directs the sample to the appropriate grade bin based on database information, (2) indicates cumulative total of number of samples classified in each grade, (3) start or stop an operation or reset all entries (4) indicates time for various operations.

Fig. 4 HMI Window for Acoustic Sorting System


E5 =INDEX(A:A,MATCH(MAX(B:B),B:B,0),1)

	A	B	C	D	E
1		Spectrum			
2	X [Frequency- Hz]	Y[Amplitude (kg/ms2)			
3	0	0			
4	32	0.002845412			
5	64	0.002618389		Dominant frequency, Hz	192
6	96	0.005528197		Maturity stage	GRADE A
7	128	0.02801159			
8	160	0.07515863			
9	192	0.1030763			
10	224	0.07699327			
11	256	0.04739659			
12	288	0.02493557			
13	320	0.02128009			
14	352	0.02079244			
15	384	0.01190955			
16	416	0.009204326			
17	448	0.02042924			
18	480	0.02011008			
19	512	0.02344685			
20	544	0.01154763			
21	576	0.01687403			
22	608	0.004422506			
23	640	0.002051045			
24	672	0.002390092			
25	704	0.005556887			

Fig. 5 Gate Activation using MS Excel

and guava (Barriga-Tellez *et al.*, 2011). Classification efficiencies of 100, 85 and 82% were obtained for mature, semi-ripe and ripe stages respectively.

Determination of Internal Defect in Brinjal

A major threat to brinjal at the international and domestic markets is the Brinjal Shoot and Fruit Borer (Leucinodes orbonalis) infestation. 30 to 70% of brinjals are susceptible to insect attack in a single cultivation plot itself (Dhas and Srivastava, 2010). At present, the only method infestation for detection available and practiced commercially is inspection by visual methods. However, there is a high risk of human errors. The acoustic responses of brinjal samples were obtained using the developed prototype. Distinct dominant frequency values were observed between uninfested (360-520 Hz) and infested brinjal (160-280 Hz) samples. This is because, an internal infestation results in longer travelling paths for acoustic responses, with lower peak resonant frequency values. Similar results were obtained for watermelon with and without internal damage by Diezma-Iglesias *et al.* (2004) and for potato with and without internal heart by Elbawati (2008). Classification efficiencies of 92 and 81% were obtained for uninfested and infested Brinjal samples respectively.

Conclusions

In the present work, a sorting system prototype was developed to determine maturity stages and internal defects in fruits and vegetables based on acoustic resonance technique. Variations in acoustic response (dominant frequency value) were used to directly correlate with fruit quality. Results were in agreement with those obtained by visual examination and destructive methods. Future work may be directed in developing databases for various other samples too and focus can be given to handle various scale-up variations. This developed system can be well utilized in processing industries, quarantine units or packing houses as a rapid non-destructive sorting technique.

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Promotion of Self-propelled Rice Transplanters in Odisha state of India

by

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Abstract

Secondary data analysis revealed that the Public Private Partnership mode of promotion of self-propelled transplanters is effective in the state of Odisha, though the spread of transplanters was not uniform across regions. The sale of number of power operated transplanters under Public Private Partnership mode has increased from a mere three units during 2005-06 to 608 during 2013-14. Primary data analysis of the transplanter owners revealed that there was a total monetary gain of Rs. 15,570 (US$ 255) and Rs. 18,220 (US$ 299) per ha in inland and coastal Odisha, respectively over manual transplanting even without extending subsidy. Though the Public Private Partnership program was effective in adoption of power operated transplanters, it was not inclusive in covering a large section of small and marginal farmers. A legal bond with the transplanter owner is required to make the program more inclusive. Prompt after sale service for the machine, training on mat type nursery raising and to driver of the transplanter is needed as assessed from the survey. Cooperation with irrigation department of Odisha is necessary for timely release of water in canals for planting.

Introduction

The process of economic development and structural transformation in a developing economy involves withdrawal of labour from agricultural sector and engagement in industrial and service sectors (Timmer, 2010). In the process of economic development, more and more labours from agricultural sector are diverted for non-farm activities. As a result, wages of agricultural labours rise and farmers try to substitute machines in place of labours to carry out various agricultural operations. The era of unlimited labour supply has already passed in rural China (Xiaobo *et al.*, 2011) and the process of economic development in India has led to diversion of rural agricultural labours to other sectors of the economy. As a result, the wages of agricultural labour has increased and in the recent past, the rate of increase was observed to be faster due to operation of the mega government labour employment program like Mahatma Gandhi National Rural Employment Guarantee Scheme (Gulati *et al.*, 2013). Due to continuous rise in wages, the profit margins from rice cultivation have decreased year after year in different states (Narayanmoorthy and Suresh, 2012; Samal, 2013). Further, rural youths are reluctant to attend various agricultural operations due to more drudgery involved in such operations in comparison to jobs in non-farm sector. Therefore, mechanization of different operations in paddy cultivation has become inevitable to reduce labour use in production process and reduce drudgery. Moreover, agricultural machineries increase productivity of land and labour by meeting timeliness of farm operations and increasing work output per unit time. The sequential adoption of mechanization, first for power intensive operations (land preparation, pumping water, transport, threshing, milling, etc.) and then for control intensive operations (transplanting, weeding, shifting, winnowing, etc.) is a farmer response induced by changing relative prices of factor inputs (Pingali, 2007) like human labour, animal labour, chemicals, machineries, etc. In the initial stage, government ought to play a facilitating role in the acquisition and maintenance of mechanical technologies as the initial cost of acquisition of machineries is relatively high. In the process of facilitation, this may require some capital subsidies in the beginning.

Odisha is an agrarian state with 83% of its total population (42 million) living in rural areas. Rice crop covers maximum area (4.02 million ha) among all crops in Odisha. The studies relating to formulating long-term mechanization strategies for each agro-climatic zone / state of India have recommended introduction of rice transplanters in Odisha (Annamalai, 2010 and Pandey, 2010). Rice cultivation is labour intensive and the operations where very little mechanization has taken place are transplanting and weeding. Availability of labour is a major problem during transplanting for which Government of Odisha has decided to introduce power operated rice transplanters in Public Private Partnership (PPP) mode during 2004. Promotion of rice transplanters in PPP mode not only improves the efficiency in paddy cultivation but also increase effective extension services and faster pro-rural innovative activity in the agricultural sector. Government is providing subsidy to farmers for purchase of transplanters and no study has been conducted to assess the effectiveness of the program and how different regions of Odisha and different categories of farmers have benefitted from the program. Therefore, this study was planned to study the effectiveness of PPP in promotion of rice transplanters in different regions of Odisha and also to study the equity aspects. The hypothesis set for the study was that all the zones and all categories of farmers of Odisha have equally benefitted from the PPP program on promotion of self-propelled rice transplanters by the Government of Odisha.

Means and Methods

During 2004, three models of self-propelled rice transplanters from three firms were approved by Government of Odisha for promotion by extending subsidy. A list of farmers who have purchased transplanters in PPP mode up to the year 2011-12 was obtained from the office of the Agriculture Promotion and Investment Corporation of Odisha Ltd. (APICOL), Government of Odisha, during 2012. The number of power operated transplanters sold in PPP mode was 147 up to the year 2011-12. It was noticed that all the transplanters purchased by the farmers under PPP mode were of one model i.e. Yanji Shakti 2ZT-238-8 sold by VST Tillers and Tractors Ltd. This is due to aggressive marketing strategies like extension of credit to dealers, wide network and lower cost of the transplanter of the promoting firm. Therefore, it was decided to undertake the primary survey based on this model only.

Physiographically, the state of Odisha is divided into four broad zones viz. Eastern Ghats, Central Table Land, Northern Plateau and Coastal Plains (**Fig. 1**). Sixty transplanter owners from 15 districts of

Fig. 1 Map showing different zones of Odisha

Table 1 Zone wise sampled farmers (transplanter owners) surveyed in Odisha

Zone	Districts in the zone	No. of transplanter owners contacted
Eastern Ghats	Bolangir, Kalahandi, Koraput, Malkangiri, Nawarangpur, Nuapara, Rayagada and Sonepur.	25 (60)
Central Table Land	Angul, Bargarh, Boudh, Deogarh, Dhenkanal, Jharsuguda, Kandhamal and Sambalpur.	9 (23)
Northern Plateau	Keonjhar, Mayurbhanj and Sundergarh.	8 (19)
Coastal Plains	Balasore, Bhadrak, Cuttack, Ganjam, Gajapati, Jagatsinghpur, Jajpur, Kendrapara, Khurdha, Nayagarh, Puri.	18 (45)
Odisha	30	60 (147)

Figures in parentheses indicate actual number of transplanters available in the zone up to 2011-12

Odisha were selected on the basis of random sampling with probability proportion to the number of transplanters available in each zone up to the year 2011-12. The number of samples selected from each zone is mentioned in **Table 1**. Data on area coverage by each transplanter (both own farm and on custom hiring basis), number of small farmers covered, irrigation availability by source, training needs and availability of after sale service etc. were collected from the transplanter owners with the help of a questionnaire. The cropping season for which data on area coverage and number of farmers covered refers to the year 2012-13 (wet and dry seasons). As machine transplanting requires mat type seedlings, labour requirement for different operations of mat type nursery raising along with materials required were also collected from the transplanter owners along with labour and material required for normal method of nursery raising. The depreciation of the machine was taken into account while computing the cost of planting mat type seedlings. As the wage rates of three zones viz. Eastern Ghats, Central Table Land and Northern Plateau were similar, these three zones were combined and reported as inland Odisha for computing cost of nursery raising cum planting and compared with similar method of nursery raising in the Coastal Plains zone, where wage rate was higher during the survey period. Further data collection to assess the progress of sale of transplanters in PPP mode was made from the office of the Director of Agriculture and Food Production (DAFP), Odisha for the years 2012-13 and 2013-14, as the system of sale was changed from manual to online system from the year 2011-12 onwards. Total area coverage and irrigated area under rice in different districts were also collected from the same office and the share of each zone in total area and number of transplanters available per thousand ha of irrigated area was computed. Tabular method was used to analyze the data. In the process of study, other stakeholders like officers of the state department of agriculture and dealers of the machines were contacted to cross check the data.

Results and Discussion

Odisha has a total geographical area of 15,571 thousand ha out of which 6,180 thousand ha (39.7%) is cultivated area (**Table 2**). The distribution of cultivated area in Eastern Ghats, Central Table Land, Northern Plateau, and Coastal Plains zone was 30.2%, 21.3%, 17%, and 31.5%, respectively during 2012-13. Rice is the main crop of the state and covered about 45% of the gross cropped area (8.88 million ha). Eastern Ghats, Central Table Land, Northern Plateau, and Coastal Plains zone accounted for 27.4%, 19.9%, 16.5% and 36.2% of the total rice area (4.02 million ha), respectively. Rice is grown in two seasons in the state i.e. wet (May to December) and dry (December to May). The wet and dry season rice accounts for 93% and 7% of total rice area, respectively. The dry season rice is totally irrigated, while 47% of the wet season rice is irrigated. The availability of transplanters per thousand ha of irrigated area is about two and it varies from zone to zone. It was least in Northern Plateau zone. However, these numbers are very less in comparison to the available irrigated area in all the zones. Hence, there is need for its promotion with involvement of subsidy in the state for some more years. It was observed that all the transplanter owners were medium and large farmers (holding size > 2 ha) and the average land holding size of the owners was 9.5 ha. In Coastal Plains zone, the holding size of sample farmers were relatively less (6.00 ha) due to high population density and smaller holdings in comparison to other zones.

Table 2 Land holding size, rice area and availability of transplanters in different zones of Odisha of the sample farmers

Year	Zones				Odisha
	Eastern Ghats	Central Table Land	Northen Plateau	Coastal Plains	
Land holding size (ha)	10.46	11.83	9.04	6.00	9.49
Geographical area (000 ha)	4,764	3,947	2,843	4,017	15,571
	(30.6)	(25.3)	(18.3)	(25.8)	(100.00)
Cultivated area (000 ha)	1,866	1,317	1,048	1,949	6,180.00
	(30.2)	(21.3)	(17.0)	(31.5)	(100.00)
Rice area (000 ha)	1,104	799	663	1,457	4023
	(27.4)	(19.9)	(16.5)	(36.2)	(100.00)
Irrigated rice area (000 ha)	499.7	426.2	229	899	2,053.90
	(24.3)	(20.8)	(11.1)	(43.8)	(100.00)
Availability of transplanters per 1,000 ha of irrigated rice area	2.59	2.94	1.35	2.19	1.94

Figures in parentheses indicate percent of all Odisha

The PPP Mode of Promotion

Due to growing labour shortage during transplanting period, Government of Odisha decided to introduce power operated rice transplanters during 2004 and accordingly three models from three firms were field tested by Odisha Farm Machinery Research and Development Centre, Government of Odisha and approved for promotion by the state level technical committee. The government has decided to extend a subsidy amount of Rs. 30,000 per transplanter, which was distributed through APICOL from 2004 wet season onwards. The application process starts from the farmer to the District Agriculture Officer (DAO) through the Assistant Agriculture Officer (AAO) of the area. After verification of land records and addresses, the concerned AAO recommends the case to the DAO. The DAO after verification of the papers issues a permit to purchase the transplanter from the identified dealer of the machine with a copy of the permit each to the Assistant Agriculture Engineer (AAE) of the area, dealer of the machine and Director of Agriculture and Food Production (DAFP), Odisha. The DAO forwards the application of the farmer to a nationalized bank of the area in case the farmer needs loan. The farmer procures the machine from the dealer after paying the balance amount i.e. cost of the machine minus subsidy declared by the government for that year in self finance cases. In case of bank finance cases, the dealer supplies the machine to the farmer after obtaining the loan amount from the bank. The dealer informs the AAE after supply of the machine to the farmer and after proper inspection of the machine, the AAE recommends the case to the DAO for consideration of subsidy release. The DAO, after verification of all the papers recommends the case to APICOL for release of subsidy to the dealer. From the year 2011-12, on-line system of issue of permit and release of subsidy was introduced as the manual system took a long time for processing. It was later noticed that there was inordinate delay in release of subsidy by the APICOL. Therefore, from the year 2012-13, government has identified Bank of India through tender process for release of subsidy to the dealer. The subsidy amount has increased in phases from Rs. 30,000 (US$ 493) in the initial years to Rs. 150,000 (US$ 2,465) per transplanter from the year 2012-13 onwards.

Table 3 Zone wise and year wise number of transplanters purchased by farmers under PPP mode in Odisha (2004-05 to 2013-14)

Year	Zones				Odisha
	Eastern Ghats	Central Table Land	Northen Plateau	Coastal Plains	
May-04	1	2	Nil	2	5
Jun-05	2	Nil	1	Nil	3
Jul-06	3	Nil	1	1	5
Aug-07	12	Nil	1	1	14
Sep-08	18	1	2	2	23
Oct-09	7	6	8	9	30
Nov-10	10	7	1	3	21
Dec-11	7	7	5	27	46
2012-13	30	21	25	88	164
2013-14	103	101	126	278	608
Total	193	145	170	411	919

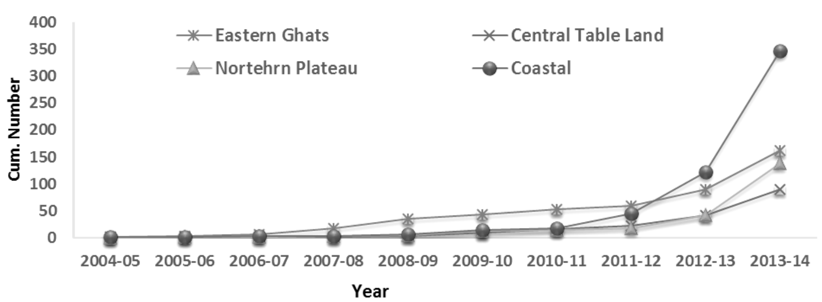

Fig. 2 Zone wise cumulative number of VST transplanters sold in Odisha (2004-05 to 2013-14)

Spread of Rice Transplanters

It was observed that the transplanters were adopted in irrigated areas only. As the transplanters require mat type seedlings and are to be planted within a fixed time frame in the main field, it is natural that only irrigated farm owners have purchased the transplanters. The adoption of transplanters in different zones of Odisha over the last 10 years is presented in **Table 3** and cumulative adoption is presented in **Fig. 2**. It was observed that the farmers of Eastern Ghat Zone, more particularly the farmers of Sonepur and Kalahandi districts within the zone, were early adopters, followed by Coastal Plains and Northern Plateau zones.

In the course of promotion of self-propelled transplanters over time, the state level technical committee has recommended 15 models of twelve firms and increased the subsidy amount to Rs. 150,000 (US$ 2,465) per transplanter from the year 2012-13. Therefore, many firms have entered the market and sold their transplanters, though Yanji Shakti 8 row model marketed by VST Tillers and Tractors Ltd was purchased by maximum number of farmers. By the year 2013-14, the cumulative sale figures of transplanters in PPP mode by different firms was 768, 93, 31, 15, 4, 3, and 2 numbers by VST Tillers and Tractors Ltd, Kubota Agriculture Machinery Private Ltd, Premier Power Equipment and Products Ltd, Greaves Cotton Ltd, Southern Agro Engineering Private Ltd, Yanmar Co Ltd India, and Kisan Kraft, respectively. Among the new firms, the model NSP-4W (4 row) promoted by Kubota Agriculture Machinery Private Ltd has made impressive progress within two years and sold as many as 86 transplanters under PPP mode. VST Tillers and Tractors

Ltd in the meantime has introduced a 4 row transplanter and sold 34 units during 2013-14. During the year 2012-13, Coastal Plains zone surpassed the Eastern Ghat zone in adoption of number of transplanters and is the leading zone now. By 2013-14, Coastal zone possesses 411 transplanters followed by Eastern Ghat zone (193), Northern Plateau zone (170) and Central Table Land zone (145). The adoption rate was only one to three in each zone during the initial three years, which has picked up during last two years, with maximum number of adoption (608) being in the year 2013-14. The above analysis shows that the PPP mode of promotion of rice transplanters is effective. However, it was observed that the spread was not uniform across zones. Therefore, the hypothesis set for the study that all the zones are equally benefitted from the mechanization program is rejected.

Economics of Transplanting

The details of cost of nursery raising and transplanting in inland and coastal Odisha are presented in **Table 4**. Though the material cost for raising mat type nursery was the same in both the regions of Odisha, the labour costs vary. The average cost of nursery raising and transplanting per ha was found to be Rs. 6,905 (US$ 113) without subsidy, Rs. 5,650 (US$ 93) with subsidy by using power operated transplanters against Rs. 12,650 (US$ 207) in manual transplanting in inland Odisha. Therefore, there was a net saving of Rs. 5,745 (US$ 94) and Rs. 7,000 (US$ 115) per ha due to use of power operated transplanters without subsidy and with subsidy, respectively in inland Odisha. In coastal Odisha, due to higher labour wages, the average cost of transplanting per ha was computed to be Rs. 7,705 (US$ 126), Rs. 6,450 (US$ 106) and Rs. 16,100 (US$ 264) in transplanters without subsidy, with subsidy and manual transplanting, respectively. The net cost saving was Rs. 9,650 (US$ 158) and Rs. 8,395 (US$ 138) by use of transplanters with and without subsidy, respectively in coastal Odisha. On an average, there was a net yield gain of 0.75 tonnes per ha in both inland and coastal Odisha. If this gain is taken into account, there was a net return of Rs. 16,825 (US$ 276) and Rs. 15,570 (US$ 255) per ha in inland Odisha due to use of transplanters with and without subsidy, respectively. Similar figures for coastal Odisha are Rs. 19,475 (US$ 319) and Rs. 18,220 (US$ 299). Besides the yield and economic advantage, the other advantages in machine transplanting as opined by the farmers were, reduction in weeding cost due to use of weeders, easier plant protection operation, less occurrence of pests and diseases, better tillering, straight planting of seedlings by machine as compared to inclined position by manual transplanting, reduction in drudgery, overcome labour shortage during peak transplanting period, saving of labour and timely transplanting, etc. On an average, there was a labour saving of 53 man-days per ha in power operated transplanting over manual transplanting.

Table 4 Economics of use of power operated transplanters vs. manual transplanting for planting 1 ha area in Odisha

Particulars	Inland Odisha		Coastal Odisha	
	Machine transplanting	Manual transplanting	Machine transplanting	Manual transplanting
Seed	1,125	1,250	1,125	1,250
Ploughing cost (Nursery area)	250	300	250	300
Iron / Wooden frame - depreciation	100	-	100	-
Plastic sheet	150	-	150	-
Straw	100	-	100	-
Fertilizers and manures	625	750	625	750
Labour for nursery raising	1,500	1,050	2,000	1,400
Labour for uprooting and transplanting	900	9,300	1,200	12,400
Depreciation, maintenance and fuel cost of the transplanter				
a) Without subsidy	2,155	-	2,155	-
b) With subsidy	1,055	-	1,055	-
Total cost				
a) Without subsidy	6,905 (113)	12,650 (207)	7,705 (126)	16,100 (264)
b) With subsidy	5,650 (93)		6,450 (106)	

Note: Wage rate for labours has been taken as Rs. 150 for inland Odisha and Rs. 200 for coastal Odisha;

Figures in parentheses indicate total cost in US dollars; 1 US$ = 61 Indian Rupees.

Area Coverage by Transplanters And Coverage of Type of Farms

Primary data analysis revealed that among the transplanter owners, 42% have used transplanters on their own farm only. Maximum owners (55%) of Eastern Ghat zone have used their transplanters on their own land followed by Central Table Land (38%) Northern Plateau zones (38%), and Coastal Plains zone (15%). The average area coverage by a transplanter in different zones is presented in **Table 5**. Ideally, a transplanter can cover 24 ha in a season. But, it was observed that on an average, a transplanter has covered 13.75 ha during wet season and 5.39 ha during dry season. When zone wise area coverage during both the seasons was considered, Northern Plateau zone was ahead of other zones followed by Central Table

Land, Eastern Ghats and Coastal Plains zone. But, when only wet season was considered, the maximum area coverage by a transplanter was in Coastal zone (17.17 ha) followed by Northern Plateau, Central Table Land and Eastern Ghat zones. The labour demand during transplanting period in wet season was the highest among all operations. There was no area coverage in Coastal zone in dry season due to sowing/planting of other crops among surveyed farms. Moreover, 58 percent of the farmers in Odisha were of the opinion that the transplanter was not fully utilized during a season.

Further data analysis on area coverage in own farm and other's farm revealed that on an average, owners have covered 10.88 ha (7.58 ha in wet and 3.30 ha in dry season) by a transplanter on their own farm and 8.26 ha (6.17 ha in wet and 2.09 ha in dry season) on other's farm involving large and small farmers. The percent of small and large farmers covered by owners on custom hiring basis is presented in **Table 6**. It is observed from the table that 53% of small farmers were extended custom hiring service of rice transplanter, though in Odisha, as per 2010-11 agriculture census (Government of India, 2012), 92% of total farmers have land holdings up to 2 ha. Hence, a large section of medium and large farmers availed the benefit of power operated transplanters and a large section of small farmers are neglected by this program. Therefore, the hypothesis set for the study that all categories of farmers are equally benefitted from the PPP program on power operated rice transplanter is rejected. When different zones were considered, Eastern Ghats and Central Table Land zone owners have covered less number of small farmers than the other two zones on custom hiring.

Table 5 Season-wise average area (ha) covered by a transplanter in different zones

Zone	Own farm		Others' farm		Total area	
	Wet	Dry	Wet	Dry	Wet	Dry
Eastern Ghats	7.52	3.97	4.14	2.35	11.66	6.32
Cental Table Land	10.20	4.60	3.45	1.85	13.65	6.45
Northern Plateau	8.29	4.80	8.13	4.70	16.41	9.50
Coastal Plains	5.66	-	11.51	-	17.17	-
Odisha	7.58	3.30	6.17	2.09	13.75	5.39

Table 6 Percentage of small and large farmers covered by owners on custom hiring

Zone	Small (< = 2 ha)	Large (> 2 ha)
Eastern Ghats	31.3 (52)	68.7 (114)
Cental Table Land	25.8 (8)	74.2 (23)
Northern Plateau	61.2 (49)	38.8 (31)
Coastal Plains	68.6 (166)	31.4 (76)
Odisha	53.0 (275)	47.0 (244)

Figures in parentheses indicate actual number of farmers.

Table 7 Number of sample farmers getting irrigation from different sources

Zone	M&M	MIP	Borewell / Dugwell	Tank / Pond	Government lift point / Stream	Multiple Sources
Eastern Ghats	17	6	14	2	1	9 (36.0)
Cental Table Land	5	-	3	3	-	3 (33.3)
Northern Plateau	3	2	2	4	-	3 (37.5)
Coastal Plains	7	1	11	2	2	10 (55.6)
Odisha	32 (53.3)	9 (15)	30 (50)	11 (18.3)	3 (5)	25 (41.7)

M&M: Major and Medium irrigation projects; MIP: Minor irrigation projects.
Figures in parentheses indicate percent of total farmers.

Availability of Irrigation

Adoption of mechanical transplanting requires timely irrigation facilities, proper training to owners on the techniques of raising mat type nursery and prompt after sale service including supply of spare parts. The availability of irrigation facilities with the owners is presented in **Table 7**. It was observed from the table that farmers use different sources of irrigation in different zones. Forty two percent of farmers have multiple sources of irrigation. Maximum percent of farmers (53) get irrigation from major and medium irrigation projects through government laid out canals followed by bore well/dug well (50), tank/pond (18), minor irrigation projects (15) and government lift points (5). The successful farmers are those who have multiple irrigation sources. More particularly, the farmers who have bore well/ dug well/ tank/ pond are the ones, who raised mat type nursery in time, were most successful in planting their main field in time. Among different zones, Coastal zone farmers have maximum percentage of multiple irrigation sources. The transplanter owners, who depend on government irrigation sources like canal irrigation from major, medium, minor and government lift irrigation projects, have complained that erratic supply of irrigation water was a major problem in raising mat type nursery and preparing the main field in time.

Training Needs and After Sale Service

The information about training needs for raising mat type nursery and prompt supply of after sale service by the dealer of the machine was collected from the owners, and the results are presented in **Table 8**. The prompt repair service is required during planting time as the machine cannot work with older seedlings and the seedlings go waste, if not planted in time. It was assessed that all the farmers need training for successful raising of mat type nursery and 92% of the farmers complained for not getting prompt after sale service. Only some farmers in Eastern Ghat zone (13%) and Central Table Land zone (12%) got prompt after sale service from the dealer. Therefore, before supply of the transplanters, it should be made mandatory to train the owner on the techniques of raising mat type nursery and repair and maintenance of the transplanter.

Policy Recommendations

The following policy implications emerged from the study to make the program more efficient and inclusive. More efforts should be made for promotion of transplanters in Northern Plateau zone. A legal bond should be executed with the owners that at least 30 small and marginal farmers per year should be covered through custom hiring by each transplanter owner and the report regarding coverage should be submitted to the District Agriculture Officer at the end of each season. Before supply of machine, training to driver and the techniques of raising mat type nursery should be made mandatory. Spare parts should be kept ready by dealers, so that the machine does not remain idle for more days, as the duration of planting time is limited. Co-operation with irrigation department is essential for timely release of water in canals for field preparation, so that planting can be taken up in time.

Conclusions

Secondary data analysis on the spread of rice transplanters revealed that PPP mode of promotion is effective in the state of Odisha. The adoption of self-propelled rice transplanter is fast in Odisha and the number of transplanters purchased by farmers in PPP mode during the year 2013-14 was 608 from a mere three numbers during 2005-06. Though the program was effective in the state in terms of spread, it was not uniform across all the zones of Odisha. Primary data analysis revealed that use of self-propelled transplanters reduced the cost of cultivation by Rs. 5,745 (US$ 94) per ha in inland Odisha and Rs. 8,395 (US$ 138) per ha in coastal Odisha without extending subsidy on transplanters. The total monetary gain per ha from power operated transplanters without subsidy was Rs. 15,570 (US$ 255) and Rs. 18,220 (US$ 299) per ha in inland and coastal Odisha, respectively due to additional yield advantage over manual transplanted plots. The labour saving due to the transplanter use was 53 man-days per ha over manual transplanting in the state.

Though the PPP program was effective in adoption of power operated transplanters in Odisha, it was not inclusive in terms of covering large section of small and marginal farmers. It was observed from the survey that 42% transplanter owners have not extended custom hiring service to other farmers and have used the transplanters in their own land only. Among the planter owners, who have extended custom hiring service, there was a bias towards medium and large farmers. Among the total farmers covered, the percentage coverage of small and marginal farmers was 53%, while 92% of farmers are small and marginal in the state of Odisha. Besides the above, there are other bottlenecks in the program also. The transplanters were promoted / sold through PPP mode without imparting proper training to operator and educating the owners the techniques of raising of mat type nursery. As a consequence, 58% of the owners are of the opinion that, the machine is underutilized during the season. Timely supply of canal water helps in timely planting. But, the farmers, who depend on supply of canal water for preparation of main field, were of the opinion that they did not get canal water in time. About 92% of the owners complained against timely supply of spare parts and prompt after sales service and all the owners were of the opinion that there is need for training on raising mat type nursery.

Table 8 Observation on after sale service and training needs (for transplanters as well as raising mat type nursery)

Figures in % of farmers

Zone	Requirement of after sale service for repair & maintenance	Training needs
Eastern Ghats	87	100
Cental Table Land	88	100
Northern Plateau	100	100
Coastal Plains	100	100
Odisha	92	100

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The Influence of the Ginning Process on Seed Cotton Properties

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Abstract

The objective of the present study was to evaluate the impact of ginning process on the quality properties of seed cotton. The ginning process were carried out on the ginning Egyptian seed cotton (extra-long staple) Giza 86 that was mechanically picked up. The saw gin-stand machine (Lummus type) was operated at four saw drum speeds (i.e., 3.14, 3.77, 4.4, and 5.03 m/s) and four levels of feed rates (i. e., 4, 6, 8 and 10 kg.min^{-1}) under four different fiber moisture content (i.e., 10.2, 8.8, 7.4 and 5.9%) to determine the effect of those parameters on the Performance of saw gin stand machine, lint quality properties and the impurities percentage. The results revealed that the fiber moisture content of 7% achieved the best lint quality properties and minimum impurities percentage. The highest ginning efficiency of 86.7% and the lowest gin stand lint losses of 0.33% associated with saw drum speed of 4.4 m/s, feed rate of 10 kg/min and lint moisture content of 8.8% d.b. Also results showed that strength was inversely proportional to the saw speed; while elongation was proportional to saw speed. The maximum value of the impurities percentage (3.6%) recorded at saw speed of 5.03 m/s, feed rate of 10 kg/min and moisture content of 10.2%.

Introduction

Ginning is the most important process to separate the seed cotton into lint (fiber) and seeds. Ginning not only preserves the fiber quality but also dramatically improves the market value of cotton price. About 85% of total cotton in the world is ginned by saw gins stand machines (Rafiq and Chaudhry, 1997). The operating parameters strongly affect the performance of ginning machines and the lint properties of cotton. The amount of water that fibers contain can greatly affect their physical properties (McCreight *et al.*, 1997). The absorption of moisture by cotton fibers changes the mechanical and frictional properties of cotton, which affects the behavior of fibers in-process (Morton and Hearle, 1997). Byler (2003) reported that for cotton ginned with three moisture treatments of seed cotton before the gin stand, the AFIS fiber length-related properties were significantly improved with moisture restoration before the gin stand. Increasing the fiber moisture content by 1% increased the mean fiber length by 0.8 mm. Anthony (1985) discussed different features of a ginning machine, such as the control and maintenance along with the humidity of the cotton and found that the humidity has a significant effect in limiting the deterioration of cotton seed and cotton fiber quality. Hossam El din (1978) and Eweida *et al.* (1984) found that the seed cotton feed rate significantly affects the capacity and the non-lint content. Columbus and Mangialardi (1996) found that high feeding rate resulted in high non-lint content in the ginned lint. Hughs *et al.* (1983).

Anthony and Brag (1987) studied the effects of varieties, harvesting regimes and ginning practices on the fiber length, and the distribution of ginned lint. It was reported that in order to minimize short fiber content and to achieve acceptable market grades, cotton should be harvested twice-over with as little weathering as possible and no more than one lint cleaner should be used at the gin. Perter and Wahba (1999) found that the short fiber content of ginned cotton is relatively correlated with fiber elongation, lint content, strength and uniformity ratio of seed cotton Anthony (1989) reported that processing cotton at a gin to minimize machinery usage and to maximize monetary returns requires a thorough understanding of the performance characteristics of individual machines. A database involving multiple moisture, trash, machine and cotton levels was developed for all routine and laboratory fiber properties before and after various ginning processes. Ranges of these variables were representative of the minimum and maximum levels normally found in spindle-harvested cotton. The database was suitable for multiple regression analyses and development for predicting equations based on the performance characteristics of individual and combined machines. Mangialardi and Anthony (2000) found that cotton fibers were cleaned at gins with saw-type lint cleaners to improve the market value, but the aggressive saws sometimes harmed the quality of fibers. The cleaning efficiency of one saw-type lint cleaner was 54% on average and the efficiencies of seed cotton cleaners used as lint cleaners ranged from 9 to 16%. There was a significant improvement in the classer's leaf grade designations when lint was cleaned with saw-type cleaners. Staple lengths tended to be shorter after cleaning with saw-type cleaners. A modified non-saw cleaner appears to be more practical and could help preserve fiber quality at cotton gins. Mangialardi and Anthony (1998) compared a traditional gin with an intelligent to evaluate fiber quality and subsequent yarn quality. The intelligent utilized one incline cleaner and one lint cleaner while the commercial gin includes an impact cleaner, a stick machine, an incline cleaner and one lint cleaner. It was found that cotton ginned by the intelligent produced yarn with higher strength than that ginned by the commercial gin. Intelligent required less ginning, which therefore reduced short fiber content and created manageable trash particles. Patil *et al.* (2006) compared a foot operated gin and a Lilliput gin having ginning output capacity of 0.311 and 2.111 kg lint/h, respectively. The 2.5% span length and uniformity ratio remained practically the same for hand ginning. So, the foot operated gin is much more suitable for farmers because it is economical and auxiliary power is not required for its operation. Whitelock *et al.* (2007) developed and evaluated a simple and useful prototype machine for ginning Egyptian cotton on laboratory scale. This could help technicians and scholars to study the effect of any treatments during operation on fiber cotton quality. The objective of this study was to determine the optimal conditions for the operation, which achieved the lowest rate damage and loss in the cotton ginning using a saw gin machine (Lummus type) and study the effect of ginning process on the technological characteristics of ginned cotton.

Materials and Methods

Field experiments were conducted at Arab gin in El-hamra city, Kafr El-Sheikh Governorate to evaluate the performance of saw gin-stand machine, Lummus Gentle Ginning System type. The general components parts are shown in (**Fig. 1**) and cross section shown in (**Fig. 2**) that is using in ginning process of Egyptian cotton varieties (extra-long staple). The cotton variety G 88 that mechanically harvested has been used in ginning process. **Table 1** summarizes the technical specifications of saw ginning machine. This machine having saws and ribs made from metal mesh (**Fig. 3A**); the gin stand consists of a set of saws rotating between the ginning ribs (**Fig. 3B**). This technique made the ginning as continuous flow process rather than batch process. Cotton enters the saw gin stand through the huller front. The saws grasp the cotton and draw it through widely spaced ribs known as huller ribs. The locks of cotton are drawn from the huller ribs into the bottom of the roll box. The actual ginning process, separation of lint and seed, takes place in the roll box of the gin stand. The ginning action is caused by a set of saws rotating between ginning ribs. The saw teeth pass between the ribs at the ginning point. Here the leading edge of the teeth is approximately parallel to the rib, and the teeth pull the fibers from the seed, which are too large to pass between the ribs.

However, ginning at rates higher than that recommended by the manufacturer usually causes reduction in fiber quality, seed damage and choke-ups. Gin stand saw speeds are also important factor; high saw speeds tend to increase the fiber damage during the ginning process. Accordingly, the experimental studies were accomplished to evaluate the performance of the gin machine under three different variables as follow:

i) Saw drum speeds: four speeds were used in this study, namely: 3.14 (150 rpm), 3.77 (180 rpm), 4.40 (210 rpm) and 5.03 m/s (240 rpm).
ii) Feed rates: four feed rates of 4, 6, 8 and 10 kg/min.
iii) Cotton moisture content: the experiments were carried out at

Fig. 1 Saw gin-stand machine (Lummus Gentle Ginning System model)

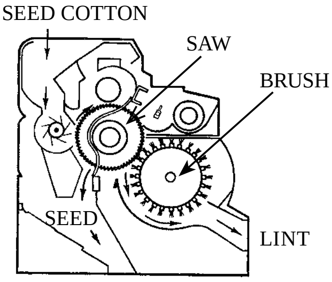

Fig. 2 General arrangement and principle operation of the cotton saw gin

Table 1 Description of the technical specifications of saw ginning machine (Lummus Gentle Ginning System type)

Item	Description
Machine made of	U S A
Overall length(front, with covers), mm	2,150
Overall width (with covers), mm	1,383
Overall height(front to bottom of feeder), mm	1,043
Weight of the machine , Kg.	815 (Approx.)
Production capacity per one hours (approx.), Kg / hour	750
Saw Shaft center line to floor, mm	730
Type & Nos. of Driving Belts	2 nos. v-belts
Type & Nos. of Bearings	21 nos. (16 ball bearing, 2-roller bearings & 3-needle roller bearings)
Power required, hp	25
Minimum distance between machines, mm	600
Floor space required (including electric motor), mm	2,360 × 1,720 × 1170
Type & consumption of lubrication	150 g. Grease per 8 hrs (approx.)
Removal of Cotton Lint	from rear
Driving of Roller Shaft	by helical gears
Saw blades, number	90
Doffing brush number, (rows of brushes)	20
Doffing brush diameter and doffing brush speed	320mm dia., 950 rpm
Saw diameter and saw speed	400 mm dia., 350 rpm

three different levels of cotton moisture content, namely: 10.2%, 8.8%, 7.4% and 5.9%.

The moisture content was determined by using the oven method according to (ASHRAE, 1999) and the following formula was used:

Moisture content = {(M1 - M2) / M2} × 100 ....(1)

Where: M1 = the moist mass (g) and M2 = the dry mass (g).

Measurements:

i) Ginning outturn: The percentage of ginning outturn was determined by using the following formula:

Ginning outturn, % = Lint mass, kg / Seed cotton mass, kg ....(2)

ii) Gin lint losses: Total weight of ginned lint losses was determined by using the following formula:

Gin lint losses, kg = weight of sample before ginning - (lint productivity, + weight of seed wastage) ......(3)

iii) Ginning efficiency, %

The ginning efficiency was determined by using the following formula:

Ginning efficiency, % = (Seed cotton mass before ginning - seed wastage mass) / Seed cotton mass before ginning ....(4)

Where, seed wastage mass is the seed cotton mass without ginning.

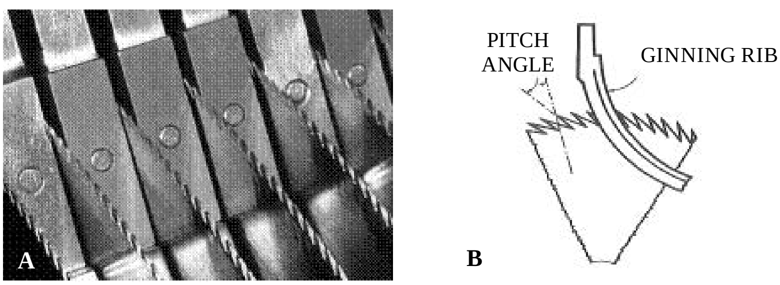

Fig. 3 Saw cylinder and ginning bars (metal mesh) photography

iv) The physical and mechanical fiber quality properties

The Physical and mechanical fiber properties were determined at fiber testing laboratory, Cotton Research Institute (CRI), Agriculture Research Center (ARC), Giza as follows:

a) Fiber length: The digital fibrograph model 630 was used to determine 2.5 and 5% span fiber length according to May and Bridges, (1995).

b) Uniformity ratio: The uniformity is calculated as the ratio between the short fiber length and the long fiber length using the following formula:

Uniformity ratio, % = (50% span fiber length / 2.5% span fiber length) × 100 ....(5)

(c) Lint Color: HVI 9000 according to ASTM (D-1684-96) estimated the lint color (reflectance Rd, % and yellowness +b)

(d) Fibers strength and elongation:

The Fibers strength and elongation were measured by using stelometer instrument at fiber testing laboratory, CRI, ARC according to (ASTM, designated D-1445-75, 1984). This instrument gives elongation reading and cotton strength (SL, %) that can be determined by using the following formula (ASTM 1984) :

Strength for length unit, g / tex = Wc × 1.5 / Ws × 100, % ....(6)

Where:

Wc = cutting mass, kg and

Ws = mass of sample, mg.

(e) The impurities percentage: Determined by using fractionator instrument in the cotton ginning research division, CRI, ARC.

Results and Discussion

Performance of Saw Gin Stand Machine

Lint turn out, %:

Data of lint turn out as affected by the different variables considered is shown in **Fig. 4**. The lint turn out was observed to increase with increasing both of saw drum speed and feed rate. Decreasing the lint moisture content from 10.2 to 7.4% tends to increase the lint turn out however, the lint moisture content of 5.9% decreased the turn out. Results also noticed that, the maximum value of lint turn out (46.2%) recorded at saw drum speed of 5.03 m/s, feed rate of 10 kg/min and lint moisture content of 7.4% d.b.; while, the minimum value (34.6%) recorded at saw speed of 3.14 m/s, feed rate of 4 kg/min and lint moisture content of 10.2% d.b.

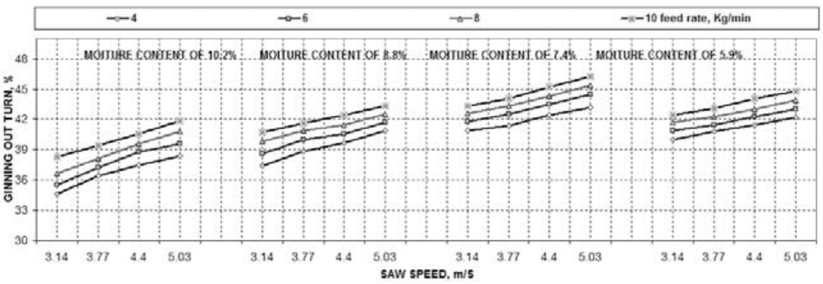

Fig. 4 Effect of saw drum speed, feed rate and lint moisture contents on ginning turn out

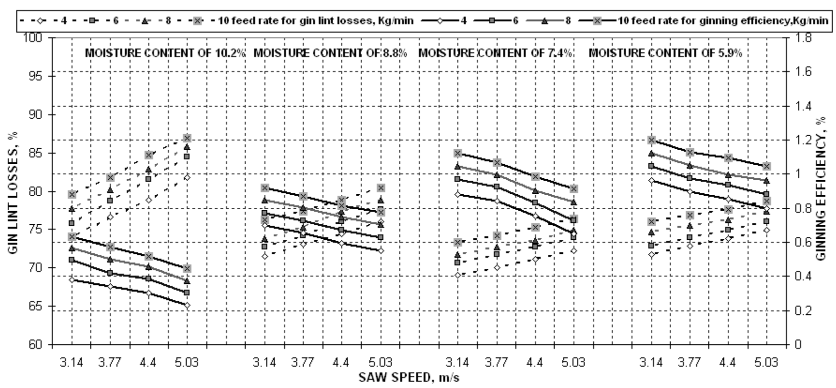

Fig. 5 Effects of saw drum speed feed rate and lint moisture contents on ginning efficiency and gin lint losses percentage

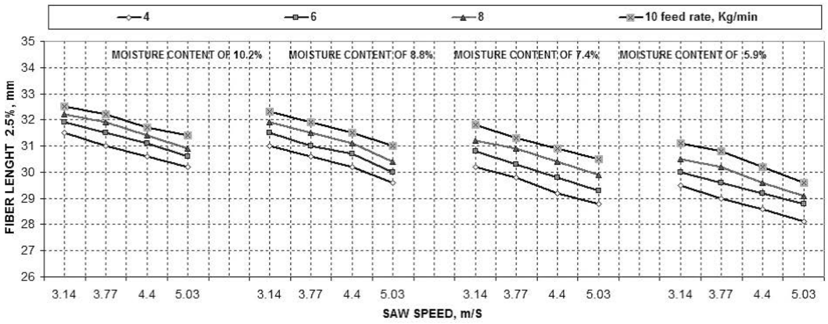

Fig. 6 Effects of saw drum speed, feed rate and lint moisture contents on fiber length, mm at 2.5% at distribution pattern

Determination of saw gin stand optimum operating conditions:

Results in **Fig. 5** illustrate the ginning efficiency and gin lint losses at all variable levels. Ginning efficiency increased with increasing feed rate and with decreasing moisture content; on the contrary, it was decreased with increasing saw drum speed. On the other hand, gin lint losses percentage increased with increasing the saw drum speed and feed rate; while it decreased with deceasing lint moisture content. Intersection points between the ginning efficiency curves and the lint losses curves can determine the optimum conditions for the machine operating; which it gives suitable efficiency with less ginning percentage of lint losses. Signing the ginning efficiency and gin lint losses curves graphically is possible to identify the optimum conditions for the saw gin machine. Accordingly the optimum operating condition for saw gin stand was recorded at saw drum speed of 4.4 m/s, feed rate of 10 kg/min and lint moisture content of 8.8% d.b. These conditions produced a ginning efficiency of 86.7% and gin stand lint losses of 0.33%.

Effects of saw gin stand on the lint properties and quality:

i) Seed cotton fiber length, mm:

Fiber length is considered an important factor that determines the cotton price in the markets. Fiber length is classified into the average fiber length, mm at 2.5% and 50% distribution pattern. **Figs. 6** and **7**

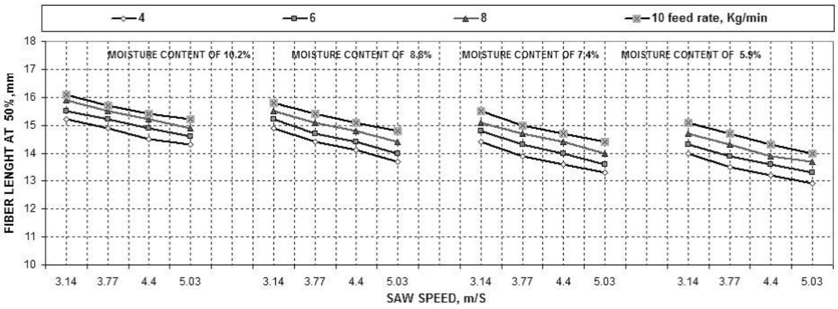

Fig. 7 Effects of saw drum speed, feed rate and lint moisture contents on fiber length, mm at 50% distribution pattern

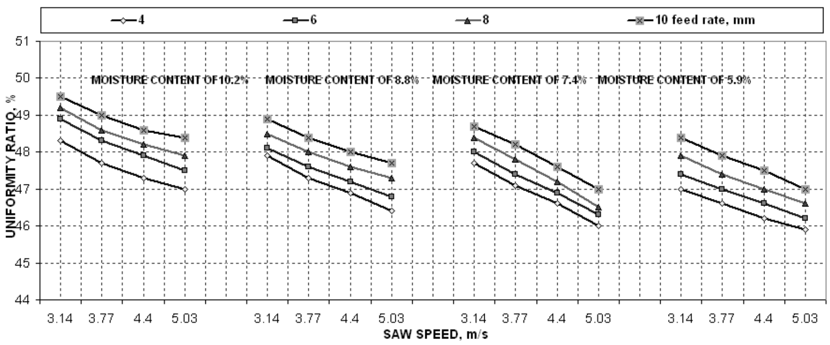

Fig. 8 Effects of saw drum speed, feed rate and lint moisture contents on fiber uniformity ratio at ginning process

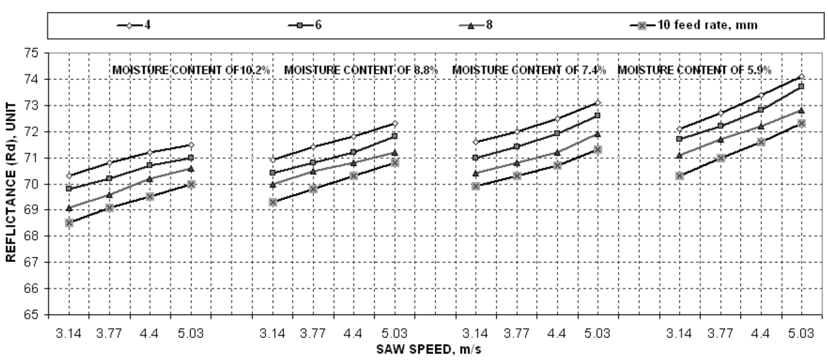

Fig. 9 Effects of saw drum speed, feed rate and lint moisture contents on fiber reflectance (Rd) at ginning process

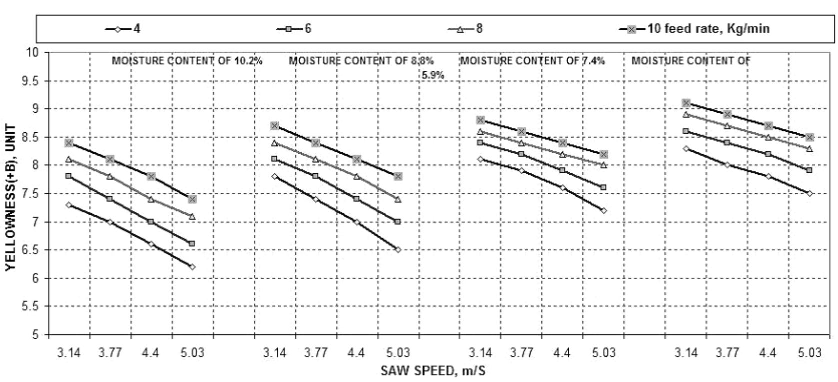

Fig. 10 Effects of saw drum speed, feed rate and lint moisture contents on fiber yellowness (+b) at ginning process

illustrate the effect of saw drum speed, feed rate and fiber moisture content on the fiber length at 2.5% and 50% in the normal distribution curve. It is clear that the 2.5% and 50% span fiber length is proportional to the lint moisture content and feed rate and inversely proportion to sow speed at all other variables. The maximum average fiber length of 32.5 mm at 2.5% in the normal distribution curve and 16.1 mm at 50% in the normal distribution curve were recorded at saw drum speed of 3.14 m/s, feed rate of 10 kg/min and fiber moisture content of 10.2%.

ii) Fiber length uniformity ratio, %:

Uniformity is considered as important fiber property along with the length and grade where they affect the industrialization efficiency and properties of threads. Fiber length uniformity as affected by different variables is shown in **Fig. 8**. The percentage of uniformity decreased with increasing saw drum speed and decreasing the moisture content. Meanwhile it increased with increasing feed rate at all combination of other variables. A maximum length uniformity of 49.5% was recorded at ginning cotton mechanically at saw drum speed of 3.14 m/s, feed rate of 10 kg/min and fiber moisture content of 10.2%.

Color Grade

Seed cotton color grade is divided into two components, seed cotton color reflectance, % and seed cotton color yellowness. **Figs. 9** and **10** indicated that the highest values of color reflectance (Rd) was 74.1% associated with the saw drum speed of 5.03 m/s, feed rate of 4 kg/min and fiber moisture content of 5.9%. On the other hand, the lowest values were 6.2 unit recorded at saw drum speed of 5.03 m/s, feed rate of 4 kg/min and fiber moisture content of 10.2%. On contrary, cotton yellowness decreased by increasing saw drum speed and decreasing both the moisture content and feed rate.

Cotton Strength and Cotton Elongation

Cotton strength (g/tex) and cotton elongation (%) are considered as extent standard for using the cotton fiber in the cotton industries. **Fig. 11** presented the effect of the saw drum speed, feed rate and moisture content on the cotton strength and its elongation. The results indicated that, cotton strength decreased with increasing the saw drum speed and decreasing fiber the moisture content; while it increased with increasing the feed rate at all combination of other variables. The maximum seed cotton strength of 29.5 g/tex, recorded at the saw drum speed of 3.14 m/s, feed rate of 10 kg/min and fiber moisture content of 10.2%. Conversely, the minimum seed cotton strength of 26.7 g/tex, recorded at the saw drum speed of 5.03 m/s, feed rate of 4 kg/min and fiber moisture content of 5.9%. In addition, **Fig. 11** illustrated that, the cotton elongation proportional to the saw drum speed and inversely proportional to the feed rate and the moisture content. The maximum elongation of 8.4%, recorded at the saw drum speed of 5.03 m/s, feed rate of 4 kg/min and fiber moisture content of 10.2%. However, the minimum elongation of 4.7%, recorded at the saw drum speed of 3.14 m/s, feed rate of 10 kg/min and fiber moisture content of 5.9%. This may attributed to exposure the fiber to little impact at these conditions.

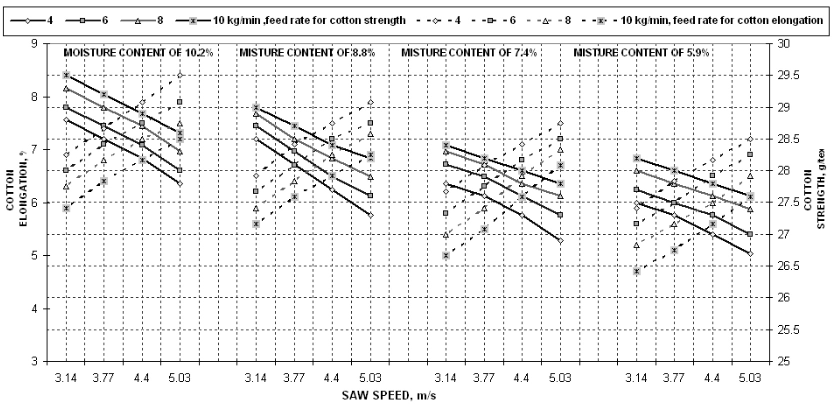

Fig. 11 Effects of saw drum speed, feed rate and lint moisture contents on the cotton strength and its elongation during ginning process

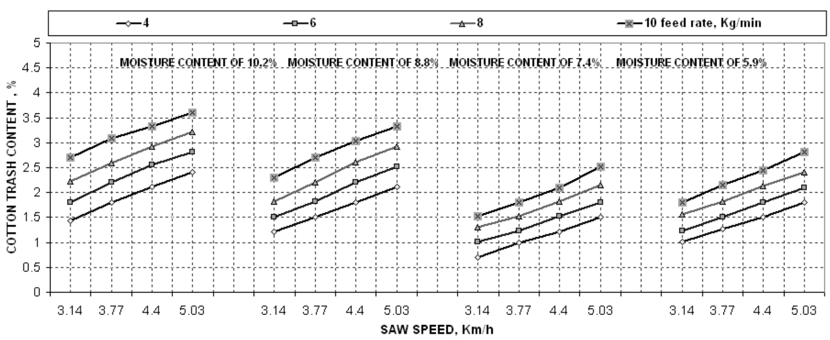

Fig. 12 Effects of saw drum speed, feed rate and lint moisture contents on the impurities percentage during the ginning process

The Impurities Percentage, %

Fig. 12 illustrated that, the impurities percentage increased with increasing both of the saw drum speed and the feed rate; while, it decreased with decreasing the moisture content. The maximum value of the impurities percentage of 3.61% recorded at saw drum speed of 5.03 m/s, feed rate of 10 kg/min and fiber moisture content of 10.2%. The minimum value of the impurities percentage of 0.7% recorded at saw drum speed of 3.14 m/s, feed rate of 4 kg/min and fiber moisture content of 7.4%.

Conclusions

The performance of a gin stand machine was evaluated by investigating the effect of the saw drum speeds, feed rate and moisture content on the seed cotton fiber quality and its properties. Specific conclusions of the study include the following:

- Lint turnout is proportional to the saw speed, feed rate and inversely proportional to the moisture content. The maximum value of lint turnout of 46.2% recorded at saw speed of 5.03 m/s, feed rate of 10 kg/min and moisture content of 7.4%.
- The maximum fiber length at 2.5% and 50% in the normal distribution curve were 32.5 mm and 16.1 mm, respectively; recorded at saw drum speed of 3.14 m/s, feed rate of 10 kg/min and fiber moisture content of 10.2%. The percentage of length uniformity was 49.5% at the above conditions.
- The maximum value of color reflectance (Rd) (74.1%) was recorded at saw drum speed of 5.03 m/s, feed rate of 4 kg/min and fiber moisture content of 5.9%. On the other hand, the minimum value of color yellowness (6.2 units) was achieved with a saw drum speed of 5.03 m/s, feed rate of 4 kg/min and fiber moisture content of 5.9%.
- Strength was inversely proportional to the saw speed; while elongation was proportional to saw speed. The maximum value of the impurities percentage of 3.6% was associated with the saw speed of 5.03 m/s, feed rate of 10 kg/min and moisture content of

10.2%.

- The optimum operating conditions for the Jumbo saw gin stand machine were recorded at saw drum speed of 4.4 m/s, feed rate of 10 kg/min and lint moisture content of 8.8% d.b.

Acknowledgements

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Design Analysis and Optimization of Rotary Tiller Blades Using Computer Software

by

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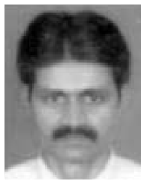

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Abstract

Technologies and computer capacity currently available allows to employ design software and numerical methods to solve complicated problems in very wide disciplines of engineering specially in field of agriculture. In this study finite element analysis of three types of rotavator blades (i.e. C-shaped, Hatchet-shaped and L-shaped) were carried out using Solidworks and ANSYS software. 3D models of different blades were designed using Solidworks software and static structural analyses of these blades were carried out using ANSYS software. The material and dimensions of C-shaped and Hatchet-shaped blade were selected as per Indian Standard IS: 6690-1981, specification for blades for rotavator. The dimensions of L shape blade were taken from the local manufacturing database of rotavator production system.

Results obtained through simulation of three types of rotavator blades indicated that maximum deformation, maximum equivalent stress, maximum principal stress and maximum shear stress occurred in Hatchet-shaped blade and minimum deformation and different stresses occurred in C-shaped blade. Hence Hatchet-shaped blade is more susceptible to failure compared to C-shaped blade during operating conditions. The Solid works designxpress module was utilized for the optimization study of three types of rotavator blades. In the optimized design of C-shaped blade, Hatchet-shaped blade and L-shaped blade maximum equivalent stress, total deformation and mass was reduced as compared to initial design.

Introduction

Rotary tillers are the tillage machine used for both the primary and secondary tillage operations. Rotary tiller is a tillage machine used in arable field and fruit garden in agriculture. This machine has a huge capacity for cutting, mixing topsoil and preparing the seedbed directly. Additionally, a rotary tiller has a mixing capacity seven times more than a plough (Shinde *et al.*, 2011). This tool decreases the soil traffic to a great extent by blending the soil. Using rotary tiller is increasing nowadays because of its various benefits. Its components works under miscellaneous forces (various forces developed during filed operations because of power, vibration, pointless, impact effect of soil parts as after reaching to higher side). The design optimization and manufacturing errors can be minimized by its components design analysis and optimization. Especially blades and transmission elements have to be reliable in field the performance against to operating forces. Predicting to stress distributions is so important for the designers, manufacturers and end user.

Helping with developed technologies and design software which integrated in new generation computers, designs are getting easier and reliable. Designers can design own products in virtual screen and they can evaluate working condition (actual operating conditions of implement during field operations) of the products by simulating techniques using the computers. Today three-dimensional (3D) modeling and finite elements method are getting so widespread in the industry. Many of 3D modeling and finite elements application samples can be seen on different engineering disciplines.

The design optimization of tillage tool is obtained by reducing its weight, cost and by improving a field performance. The computer aided design analysis by preparing a three dimensional solid modelling and finite elements method are getting so widespread in the industry. Thus due to undesired stress distributions on its componants, it cannot compensate to the operating forces i.e field environment and results in breakdown and failure due to higher stresses and deformation.

Typically, an element of a machine can work without failure but it doesn't mean that it has best design. Today's competitive industry forces manufacturers to generate the best design for their products. In the context of this research, this can be defined as an optimization problem and it can be formulated and solves mathematically. Today, computer integrated optimization techniques are used to obtain the best design parameters for products. The mathematical meaning of optimization is to obtain the conditions (parameters), which give maximum or minimum magnitude of a function. A design optimization problem is defined with three constituents, which are design parameters (variables), design constraints, and goal functions (objective functions).

In this study, three types of blades of a rotary tiller, which was designed and manufactured by a local manufacturer, was modeled using Solidworks 3D parametric design software. After 3D modeling procedure, a simulation study was carried out on the transmission gear train using ANSYS finite elements software.

Review of Literature

Topakci *et al.*, (2010) conducted deep tillage optimization by means of finite element method; case study for a subsoiler tine. The study focused on obtaining optimum geometry parameters of a subsoiler tine by using computer aided engineering (CAE). A field experiment was conducted to determine draft force of the subsoiler. The results from the experimental study were used in the finite element analysis (FEA) to simulate stress distributions on the subsoiler tine. The maximum equivalent stress of 432.49 MPa was obtained in the FEA. Visual investigations and FEA results showed that according to the tine's material yield stress point of 355 MPa, plastic deformation was evident. Based on the FEA results, an optimization study was undertaken to obtain optimum geometry parameters without the occurrence of plastic deformation. According to the optimization study, optimum parameters of the tine geometry and maximum equivalent stress of 346.61 MPa were obtained. In addition to this, the total mass of the tine was reduced by about 0.367 kg.

Shinde *et al.*, (2011) conducted the structural analysis of rotary tillage tool on the basis of finite element method and simulation method using CAD-software. The energy constrained for the tillage tool applications with 35 hp and 45 hp power tractor and estimated forces acting at soil-tool interface. The proposed work resulted in identifying sufficient tolerance in changing the dimensions of rotavator frame sections and side gear box for removing the excess weight in a solid section and also to raise the weight of blade for a reliable strength. The present working model with tillage blade is analyzed to new design constraints with change of its geometry for the maximum weed removal efficiency by presenting its practical results from the field performance.

Alavi and Hojati (2012) carried out modeling of soil cutting process in rotary tillers using finite element method. In this study, the process of soil cutting was modeled using Finite Element Method (FEM) considering the effect of forward speed, rotary speed and soil moisture content on rate of stress applied to the soil. It was concluded that increasing forward speed led to decrease in the applied stress and increasing the rotary speed and soil moisture content led to increasing the applied stress on soil. The rate of stress in different conditions was compared with the allowed stress in soil and also the additional stress that led to aggregate powdering (stress required to break soil clods and convert soil in to powder foam) was computed.

Objectives

1) To prepare a geometric solid model of different types of rotavator blades and generate a CAD analysis.
2) To compare existing rotavator blades and optimize the design parameters.

Materials and Methods

There are three types of blades selected for structural analysis using finite element method. The finite element model have the capability to predict the effect of forward speed, rotary speed, and soil conditions on stresses producing during cutting process in rotary tillers. Following three types of blades were selected.

1) C-shaped blade.
2) Hatchet-shaped blade.
3) L-shaped blade.

The dimension of L-shaped blade was taken from the local manufacturing database of rotavator production system and material selected as per Indian standard (IS: 6690 – 1981, specification for blades for rotavator). In case of C-shaped and Hatchet-shaped blade the dimensions and material were selected as per Indian standard (IS: 6690 – 1981, specification for blades for rotavator) (**Table 1**).

Building the Model

A solid model of rotavator blades were created using Solidworks software (**Fig. 1 a, b & c**). The study was focused on the deformation of a single blade of the rotavator. Therefore, all components of the as-

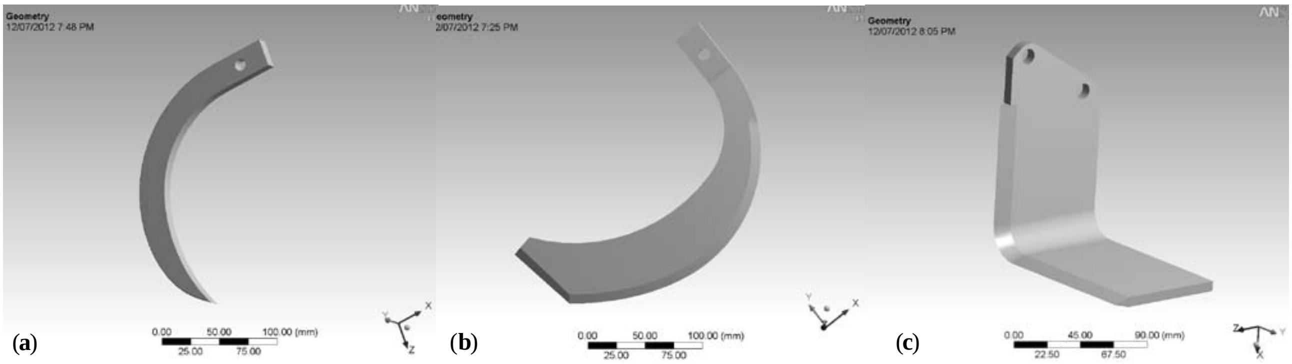

Fig. 1 (**a**) Solid Model of C-shaped blade, (**b**) Solid Model of Hatchet-shaped blade, (**c**) Solid Model of L-shaped blade

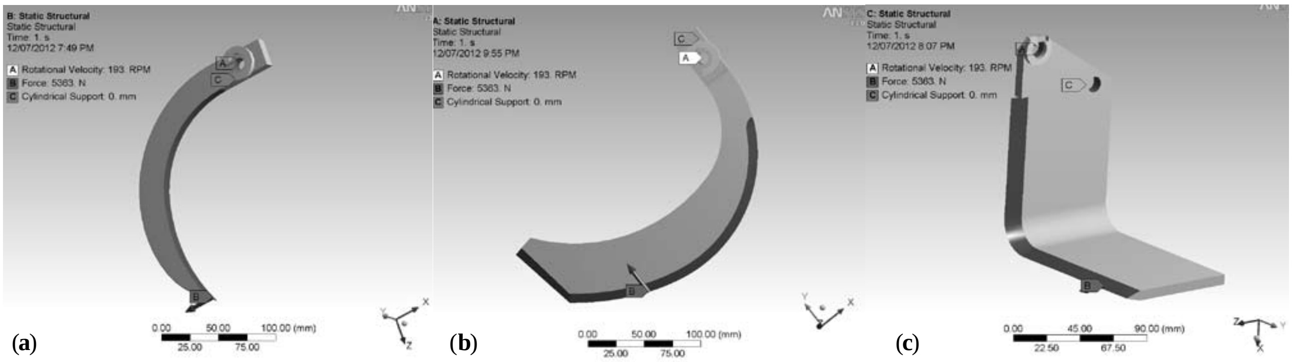

Fig. 2 (**a**) Boundary conditions of C-shaped blade, (**b**) Boundary conditions of Hatchet-shaped blade, (**c**) Boundary conditions of L-shaped blade

sembled solid model of the rotavator were not used in the FEM analysis. The commercial FEM software package, AnsysWorkbech, was utilized for the FEM stress analysis process. The FEM analysis was set up in 3D, linear, static and isotropic material model assumptions.

Mesh Generation

To build the finite element model, the blade was meshed using SOLID45, a higher order three-dimensional solid element, which has a quadratic displacement behavior and is well suited to model irregular meshes. The element is defined by 8 nodes having three translational degrees of freedom at each node. Very dense mesh was used to obtain a highly accurate quantitative analysis. **Table 2** shows the total number of elements and nodes obtained during meshing operation in different types of blades.

Boundary Conditions

The boundary conditions are the critical factors for the correctness of calculation. The mechanics of boundary conditions involved in this study were peripheral force and angular velocity of the blade. For 45 hp tractor, maximum peripheral force of 5,363 N and rotational velocity of 193 rpm were calculated and applied as boundary conditions of the blade (**Table 3** and **Fig. 2 a**, **b** & **c**).

Table 1 Material properties of C-shaped, Hatchet-shaped and L-shaped blades

Material Name	Material Properties		
	Elastic Modulus (GPa)	Poission Ratio	Density (kg/m^3)
High Carbon Steel	197	0.29	7480

Table 2 Element and node counts in mesh structure of the blades

Type of blade	No. of elements	No. of nodes
C-shaped blade	141,880	201,017
Hatchet-shaped blade	27,579	46,406
L-shaped blade	49,397	76,852

Table 3 Parameters selected for FEA of the blades

Parameters	Value
Tractor rated power (hp)	45
Speed of operation (km/h)	4
Depth of operation (cm)	15
Rotor radius (cm)	22
Rotational velocity (rpm)	193
Peripheral force (N)	5,363
Type of soil	Silt loam
Optimum moisture content (%)	5.8

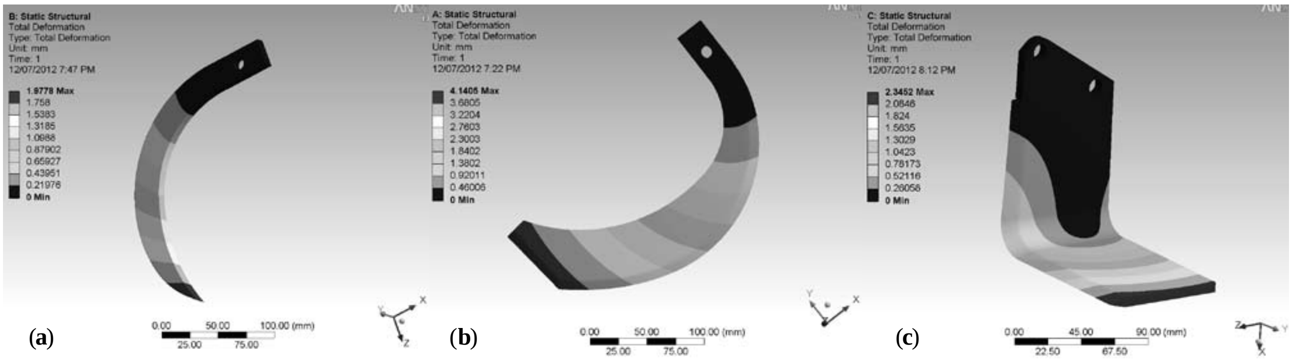

Fig. 3 (**a**) Total Deformation of C-shaped blade, (**b**) Total Deformation of Hatchet-shaped blade, (**c**) Total Deformation of L-shaped blade

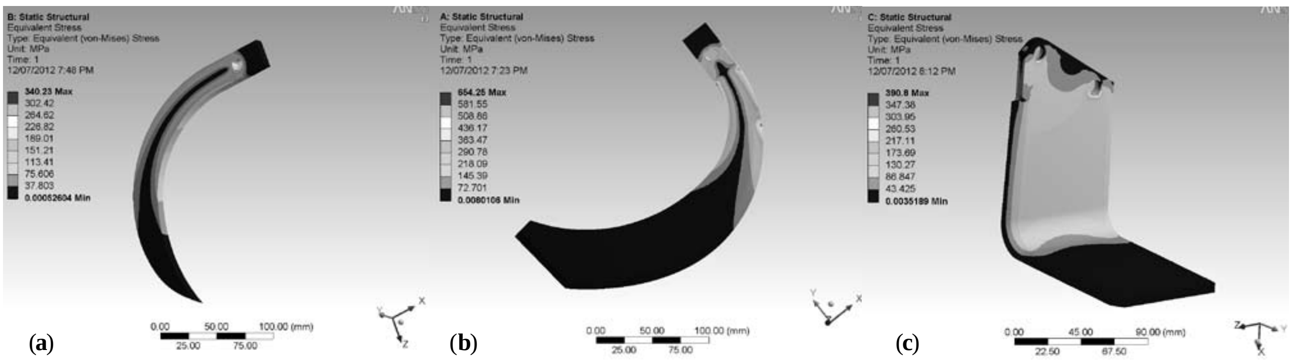

Fig. 4 (**a**) Equivalent stress of C-shaped blade, (**b**) Equivalent stress of Hatchet-shaped blade, (**c**) Equivalent stress of L-shaped blade

Results and Discussion

Static analysis was used to determine the displacements stresses, strains and forces in structures or components due to loads that do not induce significant inertia and damping effects. Steady loading in response conditions are assumed. A static analysis can be either linear or nonlinear. In this study linear static analysis was considered. Parameters such as deformation, equivalent stress, principal stress and shear stress were simulated in ANSYS software.

Results of simulation showed that maximum deformation was observed as 1.98, 4.14 and 2.34 mm for C-shaped, Hatchet-shaped and L-shaped blade respectively at the given boundary conditions while maximum equivalent (von-mises) stresses of 340.23, 654.25 and 390.80 MPa were observed for C-shaped, Hatchet-shaped and L-shaped blade respectively. (**Fig. 3 a, b** & **c** and **Fig. 4 a**, **b** & **c**).

Maximum principal stresses were found as 309.07, 656.26 and 565.86 MPa for C-shaped, Hatchet-shaped and L-shaped blade respectively, whereas maximum shear stresses were observed as 194.07, 327.60 and 210.63 MPa for C-shaped, Hatchet-shaped and L-shaped blade respectively (**Table 4** and **Fig. 5 a**, **b** & **c** and **Fig. 6 a**, **b** & **c**).

Results obtained through simulation of three types of rotavator blades indicated that maximum deformation, maximum equivalent stress, maximum principal stress and maximum shear stress occurred in Hatchet-shaped blade and minimum deformation and different stresses occurred in C-shaped blade. Minimum factor of safety was found in case of Hatchet-shaped blade whereas higher factor of safety was

Table 4 Deformation and stresses of rotavator blades

Type of blade	Total deformation (mm)	Maximum equivalent (Von-Mises) stress (MPa)	Maximum principal stress (MPa)	Maximum shear stress (MPa)
C-shaped	1.977	340.23	309.07	194.07
Hatchet-shaped	4.14	654.25	656.26	327.6
L-shaped	2.345	390.8	565.86	210.63

Table 5 Factor of safety of rotavator blades

Type of blade	Minimum safety factor
C-shaped	2.02
Hatchet-shaped	1.05
L-shaped	1.76

observed in case of C-shaped blade (**Table 5**). Hence, C-shaped blade is more reliable than Hatchet-shaped blade under loading conditions (**Fig. 7 a**, **b** & **c**).

Optimization of the Rotavator Blades

The Ansys Workbench DesignXplorer optimization module was utilized for the optimization study. The DesignXplorer environment is a powerful tool for designing and understanding the analysis response of parts and assemblies. A "what-if" parameter study strategy was selected in the optimization module. According to the design constraints, 45 different design sets were created within the module for all these three type of blades, and then FEM analyses were conducted for all design sets automatically by the module. Response results were set up for equivalent stress (Von Mises), total deformation and total mass of the blade.

In the optimized design of C-shaped blade (**Fig. 8 a**), the maximum equivalent stress was reduced from 340.23 to 299.35 MPa, total deformation reduced from 1.97 to 1.81 mm and mass decreased from 0.5043 to 0.4863 kg (**Table 6**). After optimization of Hatchet-shaped blade (**Fig. 8 b**) the maximum equivalent stress was reduced from 654.25 to 591.37 MPa, whereas total deformation decreased from 4.14

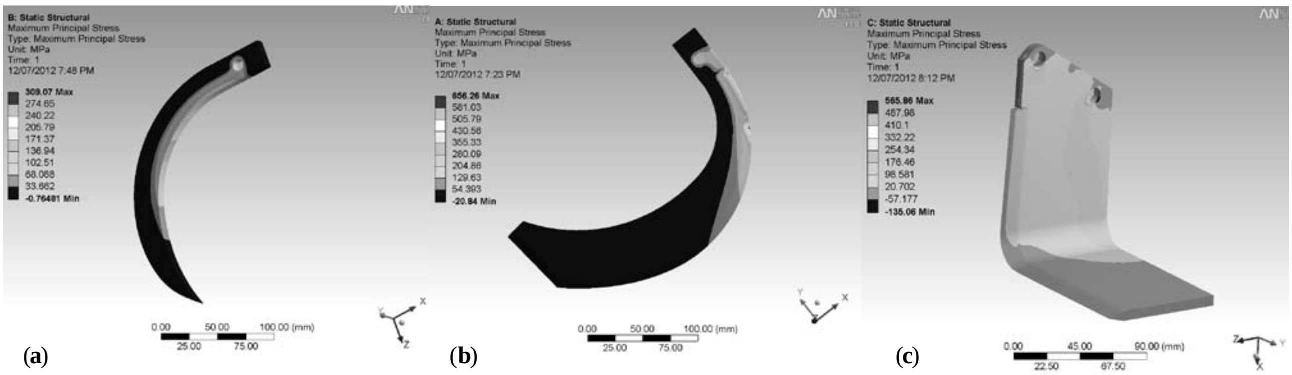

Fig. 5 (**a**) Principal stress of C-shaped blade, (**b**) Principal stress of Hatchet-shaped blade, (**c**) Principal stress of L-shaped blade

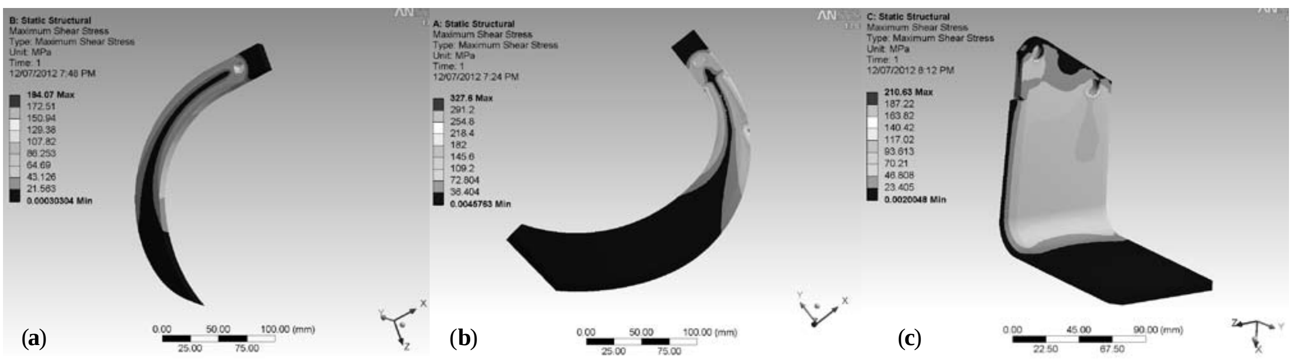

Fig. 6 (**a**) Shear stress of C-shaped blade, (**b**) Shear stress of Hatchet-shaped blade, (**c**) Shear stress of L-shaped blade

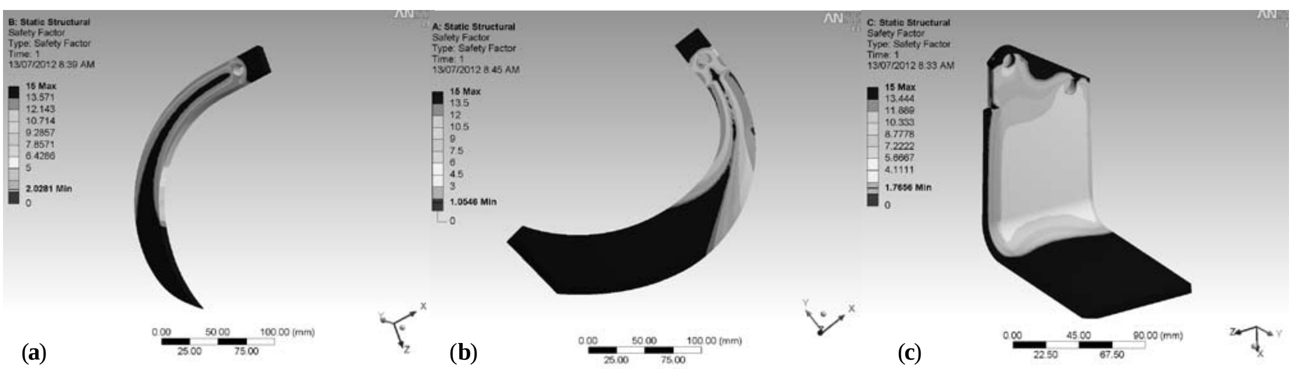

Fig. 7 (**a**) Safety Factor of C-shaped blade, (**b**) Safety Factor of Hatchet-shaped blade, (**c**) Safety Factor of L-shaped blade

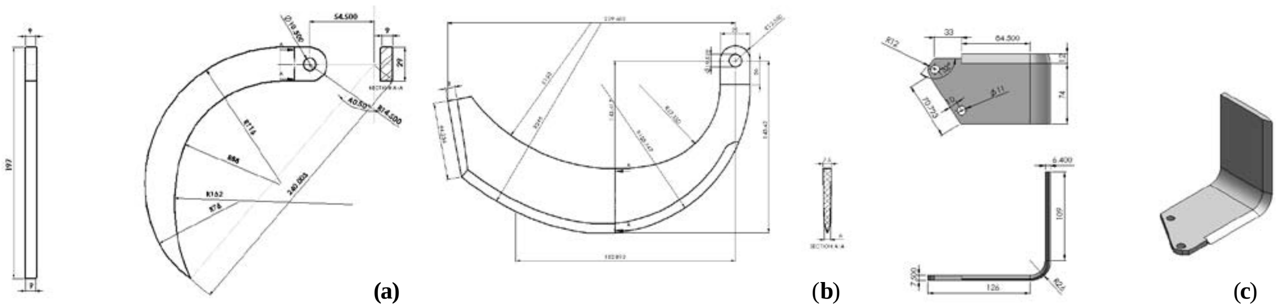

Fig. 8 (**a**) Optimized design of L-shaped blade, (**b**) Optimized design of Hatchet-shaped blade, (**c**) Optimized design of L-shaped blade

to 4.09 mm and mass reduced from 0.6295 to 0.6132 kg (**Table 7**). In case of L-shaped blade (**Fig. 8 c**) after optimization, the maximum equivalent stress was decreased from 390.8 to 337.2 MPa, while total deformation reduced from 2.34 to 2.28 mm and mass reduced from 1.048 to 1.039 kg (**Table 8**).

The scientific literature signifies that agricultural machine of 1 kg has an equivalent energy of 62.7 MJ. The simulation applications, which are based on 3D modeling, numeric methods and optimization methods are, therefore, becoming more common in the product design area, not only for saving design time, but also to reduce manufacturing costs as well as reduction in energy consumption. Consequently, the usage of these applications in the agricultural machinery design and manufacturing process will provide important benefits to create optimum designs of the agricultural machineries and to reduce the cost.

Conclusions

This study was focused on the structural optimization of rotavator blades by means of CAE. According to the study, a number of points can be summarized as follows:

1) Maximum deformation, maximum equivalent stress, maximum principal stress and maximum shear stress occurred in Hatchet-shaped blade and minimum deformation and different stresses occurred in C-shaped blade.
2) Minimum factor of safety was found in case of Hatchet-shaped blade whereas higher factor of safety was observed in case of C-shaped blade. Hence, C-shaped blade is more reliable than Hatchet-shaped blade under loading conditions.
3) A "what-if" parameter strategy was used in the optimization study and in total, 45 design sets were created and solved. After consideration of all of the results, optimum design of rotavator blade was found under the defined conditions.
4) In optimized design equivalent stress, total deformation and mass was reduced significantly as compared to the initial design. However, the results obtained by simulation analysis of different rotavator blades are required to be tested in actual field conditions to validate the simulation model.

Table 6 Comparison of initial and final design of C-shaped blade

Blade parameter	Unit	Initial design	Final design	% Reduction
Equivalent stress (max)	MPa	340.23	299.35	12.01%
Total deformation	mm	1.97	1.81	8.12%
Mass	kg	0.5043	0.4863	3.56%

Table 7 Comparison of initial and final design of Hatchet-shaped blade

Blade parameter	Unit	Initial design	Final design	% Reduction
Equivalent stress (max)	MPa	654.25	591.37	9.61%
Total deformation	mm	4.14	4.09	1.20%
Mass	kg	0.6296	0.6132	2.60%

Table 8 Comparison of initial and final design of L-shaped blade

Blade parameter	Unit	Initial design	Final design	% Reduction
Equivalent stress (max)	MPa	390.8	367.2	6.03%
Total deformation	mm	2.34	2.28	2.56%
Mass	kg	1.048	1.039	0.85%

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Electronic Hitch Control Valve for Massey Ferguson 285 Tractors

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Abstract

An electronic hitch control valve was developed and installed on Massey Ferguson 285 tractor. The hydro-mechanical draft control system was changed to the electro-hydraulic using this valve.

The result of transient response experiments showed the stability of the system in depth control. The field experiment results showed significant differences between the two control systems in fuel consumption and wheel slip ($P<0.05$). The electro-hydraulic draft control system decreased the fuel consumption and slippage by 44.6% and 29.3%, respectively, at the maximum draft set value and ground speed, compared to the mechanical draft control system.

Key terms: Hitch control, Electro-hydraulic draft control, Tractor, Slippage, Fuel consumption.

Introduction

Today, tractor is still the basic power unit in almost all production processes in agriculture, including tillage. If the agricultural machinery is utilized more efficiently, this can offer significant savings for the farmer (Yule *et al*., 1999).

Electronic systems are used increasingly to monitor or control the field performance parameters of agricultural tractors and implements, thereby improving machine performance and reducing operator physical effort (Scarlett, 2001). Scarlett (1993) reviewed tractor control system developments and proposed an integrated control system. Several implement control systems have been invented for hitched or trailed implement (Schuber and Orbach, 2000; Wiegard and Hanks, 1985) which include a control unit to generates control signals, potentiometer to measure the position of the rockshaft, force transducers to sense the load in the lower links and solenoid valves to control the flow of the pressurized hydraulic fluid to and from cylinder. An electro-hydraulic draft control system was developed (Ayers *et al*., 1989) and tested in a soil bin. Pranav *et al*. (2012) developed an automatic wheel slip control system for 2WD tractors. The performance data indicated a significant reduction in fuel consumption per hectare (20-30%), increase in field capacity (7-38%), and gain in tractive efficiency (4-10%) with slip control system versus the existing draft control system. Ismail *et a1*. (1981, 1983) developed a slip control system that maintained wheel slip in a specified range by adjusting implement depth. Comparison tests showed that the slip control and the "slip and draft" control systems gave higher mean tractive efficiency than the mechanical control system. Kolator (1999) used a tractor equipped with a Bosch electronic control system (EHR system) for field experiments. Results showed, during the use of mechanical control system, the maximum amplitude of the implement working depth and the pulling force were 16 cm and 7.83 kN, whereas with the electronic control these values were 6.74 cm and 5.76 kN, respectively. Chancellor and Zhang (1989) developed an automatic wheel slip control system for tractors. Field tests with plowing and disk harrowing showed average fuel saving of 7.6% and average time saving of 4.9% per unit area tilled.

The Mechanical Draft Control Systems of MF 285 tractors are found to be inefficient in draft control, leading to an excessive load on the tractor. Because there is no other way to increase the sensitivity of the draft control system, as it improves the implement control. Researchers have also concluded that commercial draft control systems force the operator to control the depth control lever frequently to achieve the optimum draft, resulting in poor efficiency (Pranav *et al.*, 2012; Cowell and Milne, 1999). So, it is necessary to develop an electronic draft control system with an appropriate sensitivity, inexpensive and suitable for locally manufactured tractors.

The objectives of this study are: (1) to design and construct a new directional and proportional flow control valve for use in the Electro-hydraulic Draft Control System(EDCS) (2) to investigate response characteristics of the control system and (3) to compare its field performance with the existing Mechanical Draft Control System (MDCS) on the same tractor.

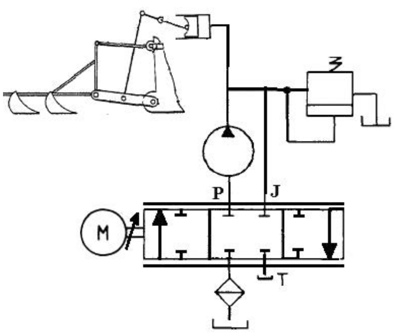

Fig. 1 Hydraulic circuit of MF 285 tractor

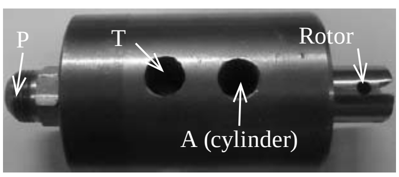

Fig. 2 Constructed control valve

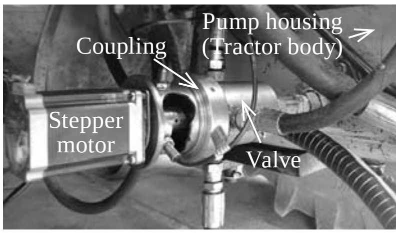

Fig. 3 Overview of the installed control valve and stepper motor on the MF285 tractor

Materials and Methods

Directional and Proportional Flow Control Valve

The hydraulic circuit of MF 285 tractor is illustrated in **Fig. 1**. The hydraulic system is single acting using a fixed displacement pump with a control valve at the pump inlet.

A new directional and proportional flow control valve with capability of being controlled by stepper motor was designed, constructed and installed in the hydraulic circuit. This valve design is as rotary type. In this prototype the rotor is rotated with respect to the valve body (cylinder) by the stepper motor. When the rotor is placed in the selected positions, ports in the valve body are connected in various combinations to provide lifting, neutral or lowering commands and the three point hitch linkage is moved according to the valve operation (**Fig. 2)**. The port connected to the pump inlet is a low pressure and the ports connected to the pump outlet or hydraulic cylinder is high pressure (20 MPa).

The most important parameter in the control valve design is the calculation of input and output ports sizes. The port sizes were calculated by the following equation:

$d_i = 4.607 \sqrt{(Q / V)}$ ....(1)

Q = Volumetric flow rate of oil, Lit/m, V = oil velocity, m/s, and d = diameter, mm.

From the tractor datasheet, the maximum flow rate of the pump at 640 rpm of drive shaft speed is 15.2 L/m. Hydraulic oil velocity in the pipe was selected from the standard table. By selecting the velocity and the maximum flow rate, diameter of the intake and outlet ports were obtained 18 and 7.4 mm, respectively. Intake and outlet port area of the control valve of the hydraulic pumps used in MF 285 Tractors are 84 and 42 mm^2, respectively.

The size calculated from equation (1) for the discharge (pressure) line is approximately equal to its actual size. But there is difference between the calculated size for the intake line and the actual value. This difference may be due to improper oil velocity selection. Finally, the diameters of the inlet and outlet ports of control valve were selected 12 and 8 mm, respectively.

In order to increase the response of control valve for opening and closing the ports with appropriate speed, the rotation angle of the valve rotor was determined to be less than 90 degrees. Therefore, the external diameter of rotor was chosen equal to 30 mm to be able to drill 12 and 8 mm holes on its circumference and not to let the valve size be too large. External diameter of cylinder was chosen equal to 60 mm to have sufficient strength against the pressure of 200 bars and have the possibility of creating the threaded holes with the proper depth to fasten the connectors and hoses. CK45 steel was used for the construction of the control valve. After the implementation of the desired plan, surface plating and hardening up to 35 Rockwell was done. Then, to create a good surface finish to prevent oil leakage at high pressure, grinding and finishing operations were done with high precision. Finally, to connect the control valve to the hydraulic pump, the holes on the tractor body and the standard connectors were used. The valve was tested under high pressure in the laboratory, and its performance was satisfactory with very least leakage. It had also good accuracy in flow and direction control of the oil entering to the hydraulic pump.

The valve was installed on the tractor in parallel to the existing valve of the hydraulic pump so that either valve could work independently. Then the stepper motor was mounted on the rear of valve by a coupling and its shaft was coupled to the rotor (**Fig. 3**). By installing and using this designed control valve on MF2 85 tractor, the MDCS of MF 285 tractor was changed to

EDCS.

The EDCS was developed and installed on the Massey Ferguson (MF) 285 tractor. This system consisted of a directional and proportional flow control valve, depth sensor, an S type tensile load cell, TD-1000 amplifier, Programmable Logic Controller (PLC), Human Machine Interface (HMI) and stepper motor with deriver's.

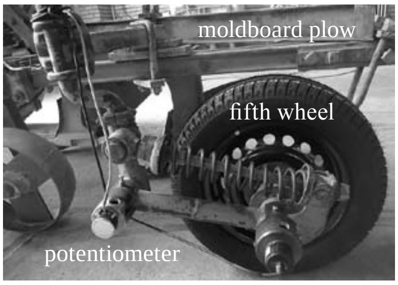

Fig. 4 Depth sensor assembly

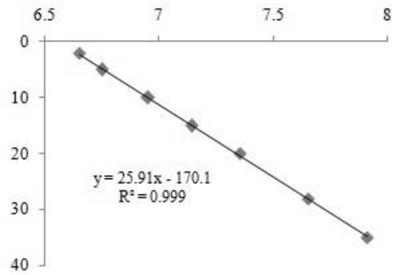

Fig.5 Calibration of depth sensor

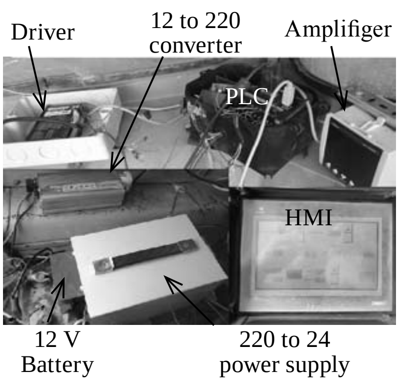

Fig. 6 Electronic component of the control system

Electro-hydraulic Draft Control System

In this study, a free- floating fifth wheel sensor assembly was mounted on the left side of the moldboard plow so that it could track the left rear tractor wheel path (**Fig. 4**). The pneumatic tire was a flotation type with a rolling radius of approximately 27 cm. A rotary potentiometer was mounted on the pivot arm of the wheel to monitor its rotation. This transducer was used to measure the angular position of the fifth wheel and to calculate the implement depth.

The calibration result of the depth sensor in the laboratory showed a linear relation between potentiometer output voltage and measured values (**Fig. 5**). Calibrations were also conducted before field testes. The difference between indicated and measured depth values obtained during field testing was less than 2 cm.

Draft force sensing was accomplished with a 50 kN tensile S type LASUX load cell. The draft force was sensed by the load cell and amplified (0-10 V) by the TD-1000 amplifier. The voltage output from amplifier was received by the analog input unit of the PLC.

An Omron Model PLC was employed to signal processing and data recording. This PLC included a CP1L-J14D CPU unit and a CP1W-AD041 analog input unit (**Fig. 6**).

The CPU Unit had eight digital input and six digital output terminals. Analog Input Unit provided four analog input terminals. The analog input signal ranges were selected from 0 to 5 volt. Analog output signals from sensors were received by the Analog Input Unit and converted to the digital value according to the input signal range and written program (conversion time, 2 ms). The averaging function was used for analog inputs. If there is only a slight variation in inputs, it is handled by the averaging function as a smooth input.

Since the torque required to rotate the valve was determined about eight kg.cm, therefore a SANYO model stepper motor (capable of producing a torque of 13 kg-cm convert to N.m) was selected. A two phase stepping Moons driver with a 24-48V DC power supply was used (**Fig. 6**). The user could select the running current and micro step resolution. The stepping angle was set on 1.8 degree.

A touch screen Programmable Terminal (PT) (NB5Q-TW00B, Omron Company product) was used to monitor the measured parameters and set the desired values, such as the tillage depth, draft force and dead zone (**Fig. 6**). NB-Designer software was used to create and modify user interfaces (graphic menus) for the PT. The user interface was created in the software and downloaded to the PT. PLC and PT were linked together by RS-232 cable.

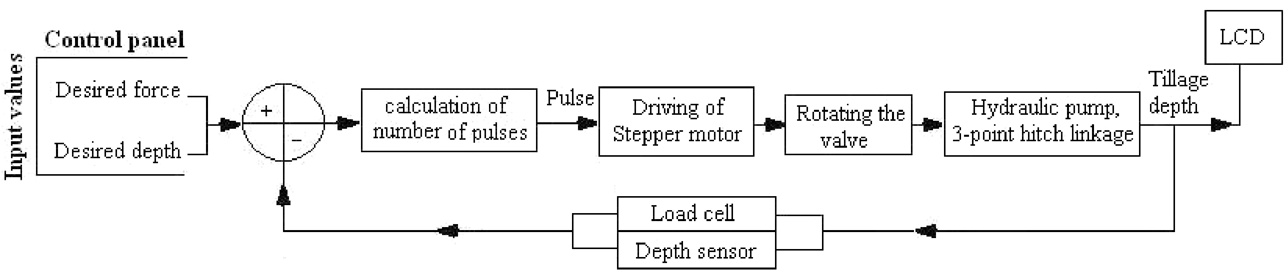

Fig. 7 Block diagram of the EDCS

Control Method

A block diagram of the EDCS is shown in **Fig. 7**. The desired values of the draft force, tillage depth and dead zone were first set in the control panel (HMI). Signals from the load cell and the depth sensor were read and the actual draft force and tillage depth was calculated at regular time intervals by the PLC. The error signal was obtained as the difference between the actual and the desired values. The error was then compared to the value of dead zone. If the error signal was within the dead zone, the stepper motor was not actuated by the PLC. If the error signal was greater than the upper limit or less than the lower limit of the dead zone, the number of pulses to control the stepper motor was calculated and the control pulse was output to the driver of motor by the digital output unit of the PLC. The motor rotated the valve in the clockwise or counters according to the signal command. The tillage depth was controlled by operating the hydraulic cylinder by the proportional operation of the valve and by lifting the three-point hitch linkage up or down.

Test Procedure

The laboratory and field experiments were performed to evaluate the performance of the control system. A MF 285 2WD tractor equipped with a developed EDCS and a two bottom mounted moldboard plow were used to perform the experiments. The transient response experiments were done to find the response and delay time of the control system in the laboratory.

The field experiments were performed in Tabriz University farm, where the soil was sandy loam with an average moisture content of 15% (d.b) and with no tillage history for two years and in randomized complete block design with three replications. The treatments included: two control systems (MDCS and EDCS), three speeds (V1 = 2.5, V2 = 3.6 and V3 = 5 km/h) and three draft set values (d1 = 6, d2 = 8 and d3 = 10 kN). The tractor engine speed was set at 2,000 rpm during field tests. For the MDCS, three positions of draft control lever were selected as the draft set values. Mean draft force obtained for three positions of the draft control lever were 6, 8 and 10 kN. Maximum tillage depth for EDCS tests was selected as 25 cm. The measured parameters for evaluation were included, fuel consumption, wheel slip, draft force, rolling resistance and implement working depth.

Fuel consumption was measured by the use of a fuel measuring system consisted of a 500 cc graduated cylinder as a reservoir and a directional valve. Draft force and rolling resistance were measured using a standard load cell attached to the front of the tractor on which the electro-hydraulic system and the plow was mounted. Another auxiliary tractor (John Deere 3140) was used to pull the plow-mounted tractor through the dynamometer (RNAM, 1983). The tractive efficiency of tractor was calculated by the following equation.

$T.E = \{P / (P + R)\}\ (1\text{-}S)$ ....(2)

Where

P = drawbar power, kN

R = rolling resistance, kN

S = wheel slip, %

The percentage of wheel slip was calculated using the following equation:

$S\% = \{(A - B) / A\} \times 100$ ....(3)

A and B: traveled distance by the tractor for 10 revolutions of tractor drive wheel under no load and on the same surface with load respectively.

Results and Discussion

Transient Response Experiment

The transient response of the system for draft force variation at two draft set values of 2 and 3 kN with a dead zone of 1 kN, the control command signal interval of 0.2 s and data sampling interval of 0.3 s are typically shown in **Fig. 8**. The desired tillage depth was selected 30 cm with a dead zone of 4 cm. Engine speed was 2,000 rpm in all experiments.

As shown in **Fig. 8**, the system performance is satisfactory in response to the draft force variations and the tillage depth has altered proportional with the draft force. The delay time of the system is less than 0.5 second and this is more related to the performance of the hydraulic unit no to the electronic unit. Results show the stability of the system in depth control when the draft force is kept in the constant value or less than the lower limit of the dead zone. It can be seen that the variations in draft force are properly followed by the system and the EDCS could keep the depth variations within ±2 cm in the steady state (4 cm dead zone) (**Fig. 8**). These results are in consistent with the results reported by Lee *et al.* (1998). Other experimental results also showed similar results in stability and deviation from the set value.

Systems Response to the Variation of the Draft Force with Time

The response of systems for actual three test area with the tractor velocity of 3.6 km/h, the control command signal interval of 0.2 s and data sampling interval of 1.5 s (the average of the last three data) are illustrated in **Fig. 9**. The set values used for EDCS were 6, 8 and 10 kN with a dead zone of 1 kN.

The standard deviations for EDCS at 6, 8 and 10 kN draft set values were 0.79, 0.82 and 0.95 kN respectively, whereas these values for MDCS were 0.73, 1.53 and 1.12 kN. As seen from **Fig. 9**, the draft variations with using of the EDCS were within the normal range of variability and any one would expect this under field conditions. Also the EDCS was capable of controlling the draft variations within acceptable boundaries. Similar results were reported by Kolator (1999) and Ismail *et al.* (1983).

Performance of the Draft Control Systems

The field data for maximum, average and standard deviation values of draft force for both control systems are presented in **Table 1**. Data indicated that the standard deviations for EDCS were lower than MDCS in the almost all treatments. As a result, the average draft value for EDCS and MDCS were 9.56, 11.14 at the highest draft set value and speed respectively (48% reduction), which led to reduction in wheel slips and fuel consumptions when using the EDCS. These finding are similar to those of Chancellor and Zhang (1989) and Pranava *et al.* (2012) that they reported lower fuel consumption with the electronic slip control system compared to the mechanical draft control system.

The results showed that the draft values were well controlled by the use of EDCS within the narrow band about the set point so that the average draft values were equal or close to the set point in all the cases. But when using MDCS, the average draft values and standard deviations were high and this caused sometimes excessive slippage for stalling of the tractor. This forced the operator to raise the implement to allow the tractor to resume normal ground speed. This type of problem did not observed when using the EDCS in the tillage operations.

Drawbar Performance

Data obtained for drawbar performance parameters, namely, tractive efficiency, fuel consumption, slippage, and tillage depth as influenced by draft force for tillage operation is shown in **Fig. 10**. The hollow and solid dots represent the performance of the EDCS and MDCS, respectively.

Based on the analysis of variance, fuel consumption and slippage values were found to be different in control systems ($P<0.05$). But there were no significant differences ($P<0.05$) between tractive efficiency and tillage depth values in both control systems.

Direct comparison of the measured data for both control systems in almost all treatments indicated that by use of the EDCS, the fuel consumption and slippage value decreased compared to the MDCS with about equal tractive efficiency. When using EDCS at the minimum speed and maximum draft set value the tractive efficiency, the fuel consumption, slippage, the tillage depth and draft force were found to be 61.3%, 33.3 L/ha, 17.9%, 24.3 cm and 9.7 kN respectively; whereas, these values were 60.5%, 42.7 L/ha, 22%, 22.8 cm and 11 kN for the MDCS. The similar result was achieved at the maximum draft set value and maximum speed so that a 7% increase in tractive efficiency, a 44.6% and 29.3% reduction in fuel consumption and slippage were obtained by using the EDCS compared to the MDCS. Similar reports on other electronic control systems were found (Chancellor and Zhang, 1989; Ismail *et al.*, 1983).

At the maximum tractive efficiency (64.1%) with the EDCS, the fuel consumption, slippage and tillage depth were 31.3 L/ha, 8% and 20.5 cm respectively; whereas, these values were 36.6 L/ha, 14% and 20.1 cm for the MDCS at the maximum tractive efficiency (62.8%). The use of EDCS led to 14.5% and 44.8% reduction in fuel consumption and slippage, respectively. This agreed with the observation of Pranava *et al.* (2012).

It can be seen, at the higher draft set value and speeds the response of the MDCS was low in draft control, resulting in poor efficiency. It can be stated that with an increase in draft set value and consequently working depth, implement weight increases and the MDCS is unable to react on time to the draft variation. This is

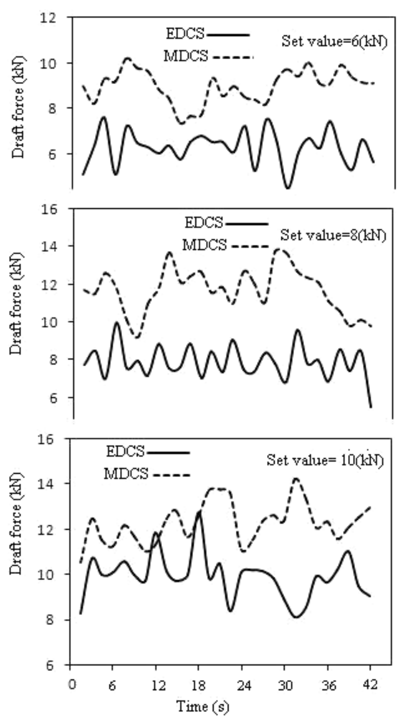

Fig. 9 Response of the control systems to the draft variations at the tractor velocity of 3.6 km/h, 1 unit in time axis= 1.5 s

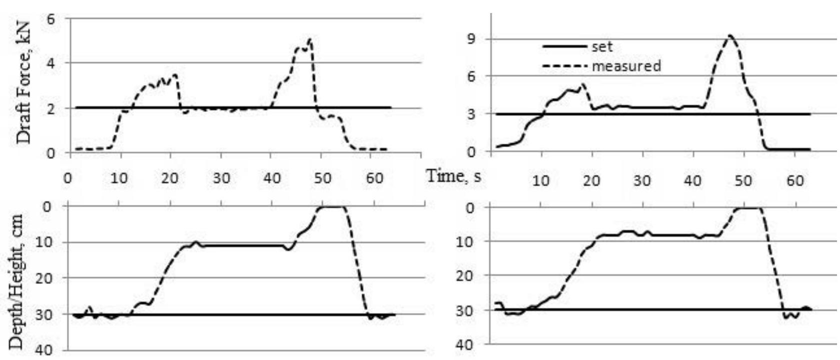

Fig. 8 Transient response of Electro-hydraulic control system. 1 unit in time axis= 0.3 s

Table 1 Performance of the draft control systems

Draft set value, kN	Speed, km/h	Electro-hydralic			Mechanical		
		Max, kN	Average, kN	Standard deviation	Max, kN	Average, kN	Standard deviation
d1 = 6	2.5	7.11	5.25	0.70	11.72	8.95	1.16
	3.6	7.59	6.22	0.79	10.42	8.70	0.98
	5.0	8.37	6.36	0.93	11.25	9.69	1.05
d2 = 8	2.5	10.00	8.33	0.95	11.63	10.00	0.88
	3.6	9.98	7.78	0.82	13.75	11.22	1.53
	5.0	9.65	7.96	0.76	13.94	9.98	1.67
d3 = 10	2.5	12.17	10.01	1.10	14.12	11.28	1.10
	3.6	11.13	9.43	0.75	14.72	10.75	1.23
	5.0	11.95	9.56	1.11	13.46	11.14	2.16

because that there is no way the rate of lift sensitivity of MDCS can be adjust to improve its response, but the sensitivity of EDCS for lifting and lowering can be set.

Conclusions

The EDCS was developed and installed on a MF 285 tractor in order to hold the draft force at a constant level regardless of soil strength variation. The result of laboratory tests showed that the system response in draft control was satisfactory and the EDCS kept the depth variations within ±2 cm in the steady state. The field results showed that the draft values were well controlled by the use of the EDCS within the narrow band about the set point so that the average draft values were equal or close to the set point in all treatments.

Acknowledgments

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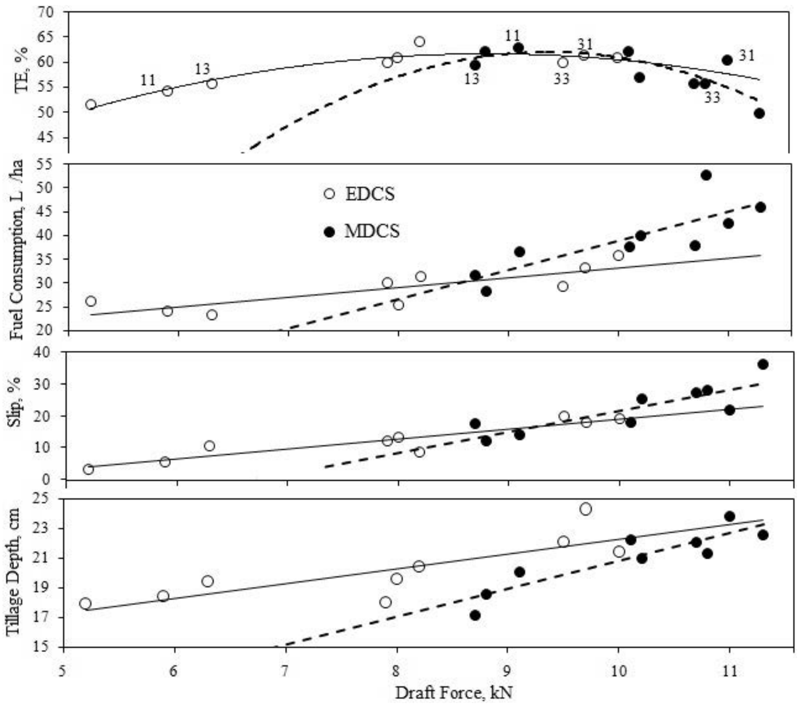

Fig.10 Drawbar performance parameters versus draft force for tilling operation: d, draft set value level; V, ground speed level

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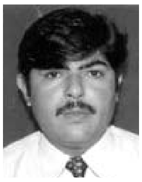
Utilization Pattern of Power Tillers in Shivalik Hills of India – A Case Study

by



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Abstract

Shortage of farm power continues to be a major productivity constraint in mountains which is almost dependent on animate power. But now use of power tillers is increasing day by day in the Shivalik hills of India. Thus, it becomes crucial to study the performance and other important aspects related to the use of power tillers with reference to the special topography and cropping patterns of this region. With this objective, a survey was conducted in two selected tehsil areas (Palampur and Baijnath) of Kangra district of Himachal Pradesh. The study involved information regarding farming practices, performance of the machine, type of operation being performed, average annual use at own farm and on custom hiring, farmer's opinion and various limitations due to the specific terrain and location. The results revealed that average annual working hours by the power tillers were 207 hours and 198 hours in Palampur and Baijnath, respectively whereas on hiring it was 182 hours in both tehsils. The major problem in operation and maintenance of the power tiller was the non-availability of spare parts and repair facilities for timely repairs at nearby places in villages/block level. The majority of the farmers (82%) were of the opinion that they got the required spare parts and repair facility beyond 20-30 km. Farmers using the power tiller were of the view that use of the machine resulted in more coverage area and saving in labour, time and reduce drudgery as compared to bullock system. Also, there was additional income generation due to custom hiring practice by the owners of the power tiller.

Introduction

The major parts of Himachal Pradesh lies in Shivalik hills of India which is situated between 30.3 and 33.3° North Latitude and 75.3-79.0° East Longitude. The elevation of the state widely ranges from 350 m to 6,975 m above mean sea level. Because of wide variations in altitude and topography, the state has broadly been classified into four agro climatic zones, i.e. sub montane and low hills sub-tropical, mid hills sub humid, high hills temperate wet and high hills temperate dry. Area under different zones of Himachal Pradesh is given in **Table 1**. The state receives 1,170 mm average annual rainfall (Anonymous 2012-13). The land under cultivation is about 10 % of the geographical area and about 82% of the net area sown is rain-fed. Rice, wheat and maize are important cereal crops of the State. The power availability in the

Table 1 Area under different zones of Himachal Pradesh

Particulars	Agro-climatic zones			
	Sub montane and low hills sub-tropical (Zone I)	Mid hills sub humid (Zone II)	High hills temperate wet (zone III)	High hills temperate dry (Zone IV)
Geographical area, 000 ha	913.2 (16.4%)	1,183.2 (21.3%)	1,280.9 (23.0%)	2,190.6 (39.0%)
Total cropped area, 000 ha	335.1 (38.0%)	383.4 (41.0%)	171.8 (18.4%)	24.3 (2.6%)
Elevation (above msl), m	< 650	651-1800	1,801-2,200	>2,201
Irrigated area, %	16.6	17.3	7.8	40.6
Rainfall, mm	1000	1,500-3,000	100	250
Field crops	Wheat, Maize, Rice, Pulses	Rice, Wheat, Maize, Barley, Pulses	Wheat, Maize, & Potato	Barley, Potato & Wheat

state is only 35% (0.70 kW/ha) of India's 2.02 kW/ha (Singh *et al*., 2014), which is very low for timely sowing of crops and, in particularly under rain-fed conditions, which occupies 82% of net cultivatable area of the state. Traditional manual tools and animal drawn implements form the mainstay of agricultural tools in the state (Singh, 2007). Several reasons can be attributed to the slow progress of agricultural mechanization in state. The state topography and small size fields make it difficult for the use of heavy mobile machinery on the steep slopes of mountains. Lack of accessible roads to the fields has aggravated this problem. Small and fragmented land holdings, high capital investment, low purchasing power of the farmers, traditional methods of farming, abundance of unemployed labour and lack of clear government policies are some other factors hindering the pace of agricultural mechanization in the state.

Shortage of farm power continues to be a major productivity constraint in mountains. The number of mechanical power sources (tractors and power tillers) is increasing day by day and replacing animal power in spite of terraced fields. Tractors are mainly used for transportation of construction material such as boulders, sand etc. and are rarely used in agriculture. Power tiller is popularizing very fast in the state due to its unique features suited to hilly undulating terrains and small size fields. It is preferred due to its small size, ease of handling on the slopes, less space requirement for turning and low initial costs. The number of power tillers in the state has been increasing at a steady pace and about 150-200 power tillers being purchased by the farmers every year. Accordingly, some of the traditional methods of cultivation have been changing. It is a well-known fact that an increase in mechanical power input in the farm leads to increase in production.

A survey based on questionnaires and visits to the farmers was planned in order to study the use of power tillers in the two selected tehsils of Kangra district of the State. In this study, the utilization and performance of power tillers was analyzed through surveys and collection of basic data to identify the problems and constraints encountered by the users.

Methodology

A questionnaire was prepared for the proposed study that included questions about the respondent such as land holding pattern and size of plots, vertical interval between plots, cropping pattern, conventional practices followed, equipment availability and details of power tiller use. The questions on power tillers included various operations performed, facilities available for repair and maintenance, availability of spare parts, difficulties faced during transportation, fuel consumption and details on custom hiring. A few questions were also incorporated on other potential uses of the machine and the socio-economic aspects related to machine use. The study was conducted in two selected tehsils Baijnath and Palampur of Kangra district of the State in the year 2011-12 at Himachal Pradesh Agricultural University, Palampur. The list of power tiller owners was collected from Department of Agriculture who provide subsidy to farmers on purchase of power tiller. A total of 60 power tiller owners were selected out of these tehsils for the study. All the primary data were collected from the farmers by personal interview. The collected data were classified and analyzed.

Results and Discussions

Socio-economic Conditions of Farmers

The information on land holding of power tiller owners was analyzed and tabulated in order to relate to the power tiller utilization. Farmers are categorized in to four groups as per their land holding; less than 1 ha, 1-2 ha, 2-4 ha and more than 4 ha. **Table 2** shows the percentage of farmers owing power tiller in each category. It is evident from the Table that in Palampur tehsil, 67.6% farmers owned power tillers who had land holdings up to 1.0 ha and these farmers had a minimum average area of land equal to 0.51 ha. Among others, 29.5% farmers owned 1-2 ha, 2.9% farmers owned 2-4 ha and no famers had land more than 4 ha. In Baijnath tehsil also, 69.2% farmers are marginal having an average land holding of 0.52 ha and are having power tillers and only 11.53% farmers under medium and large group category are having power tiller. It is clear from the Table that majority of the small and marginal farmers in hills of Himachal Pradesh own power tillers. There were only few farmers (3.84%) in Baijnath and no farmer in Palampur tehsil who had cultivable land more than 4 ha and also owned power tillers. The state statistical abstract also indicated that about 85% farmers fall under small and marginal category. More small and marginal farmers are going for the power tiller purchases because they are taking it as an additional source of income through custom hiring. The state government is also providing subsidy to the farmers on purchase of power tiller through its agriculture and horticulture departments. However, medium and large farmers have some orchards/forestry

Table 2 Land holding pattern of power tiller owners

Land holding pattern	Farmers owning power tillers, percent	
	Palampur	Baijnath
Marginal (< 1 ha)	67.6	69.2
Small (1-2 ha)	29.5	19.3
Medium (2-4 ha)	2.9	7.69
Large (>4ha)	0	3.84

and they are cultivating only a small fraction of land and also give some land on rent basis to the other small and marginal farmers.

Make and Model of Power Tillers

The information collected on the different makes of power tillers showed that 97% farmers in the Palampur and 96% in Baijnath tehsils were using the VST Shakti 130 DI make, 9.7 kW (13 hp) Mitsubishi brand power tillers and the remaining 3 to 4% famers in both tehsil were using the other make of power tiller (11 kW Kranti make). The reason for more VST Shakti power tillers in the area was because of three authorized dealers of the machine in the region. **Fig. 1** shows the percentage of different makes of power tillers in the region.

The majority of the power tiller owners in both the tehsils (59% in Palampur and 81% in Baijnath) were self operator (**Table 3**). In Palampur tehsil, 38% owner had hired an operator for operating the power tiller whereas it was only 19% in Baijnath. The wages of hired operators was given either on work hour basis or day basis. Majority of the owners who hire the operator (80-92%) were using power tiller on custom hiring whereas the owners who are self operator (65-81%) were also using power tiller on custom hiring. The age of the power tiller operators either self or hired was below 40 years. It can be concluded that unemployed youth of hills are coming forward to adopt power tiller technology as an income generating source through custom hiring.

Power Tiller Usage

The data regarding use of power tiller for different operations was also collected, analyzed and presented in **Table 4**. It was observed that every power tiller farmer (100%) in both the tehsils utilized it for rota-tilling i.e. field preparation in dry land conditions. It was also clear from the table that majority of farmers were using power tiller for sowing (first broadcasting the seed then only mixing with power tiller rotavator). For sowing of wheat in Rabi (winter) season after paddy harvesting, farmers first broadcast the seed and then go for one rota-tilling but wheat sowing after maize harvesting, farmers go for one or two rota-tilling then broadcast the seed and just mixing the seed in soil by light rota-tilling. The same practice was also followed for sowing of soybean and maize in Kharif (Rainy) season. For paddy sowing in dry land conditions, farmers prepare the field with one rota-tilling then mixing the seed after broadcasting it with power tiller. After sowing, some farmers (18-26%) use wooden planker to cover seeds with the soil which had two hooks on which rope was tied and attached to power tiller handle. During levelling, first the operator put rotavator on off position and then stood on the planker for levelling. In all other cases, levelling was done by either a manually or bullock operated wooden device. The puddling operation was performed by some farmers (16% in Palampur and 22% in Baijnath) as transplanting of paddy was done by few farmers. Rest of the farmers do direct sowing of paddy in dry and wet land conditions and then thinning after 22-25 days of sowing. Wheat thresher operated with power tiller was used by 16% farmers in Palampur and 22% in Baijnath. The power tiller utilization can be enhanced using thresher with power tiller. During idle period, power tiller was used to run atta chakki (flour mill)/rice huller by 16% farmers in Palampur and 22% in Baijnath.

Table 3 Power tiller operator and age

Tehsil / Power tiller operator, %	Palampur	Baijnath
Self	59 (65% CH*, 35% NCH**)	81 (81% CH, 19% NCH)
Hired	38 (92% CH, 8% NCH)	19 (80% CH, 20% NCH)
Self & hired	3 (100% CH)	Nil
Average age of operator, years		
Self	39	36
Hired	32	28

*CH-Custom hiring, **NCH- No custom hiring

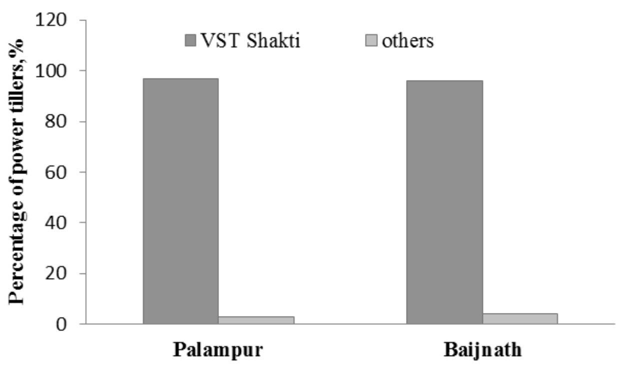

Fig. 1 Percentage of different makes of power tillers

Table 4 Type of operations performed with power tiller

Tehsil	Percentage of farmers using power tiller, %					
	Rota-tilling	Puddling	Levelling	Sowing (only mixing of seeds)	Threshing	Other (Flour grinder, rice huller etc.)
Palampur	100	16	18	76	21	18
Baijnath	100	22	26	82	27	12

Opinion about Power Tiller Attachments

Only 30-35% of the farmers in both the tehsils expressed that they were not aware of any equipment matching to the power tiller except the rotavator that is supplied as a standard attachment with the machine. Apart from the limited knowledge on the availability of the power tiller matching equipment, all other 65-70% farmers were aware of the lug type puddling wheels, cultivator, multi-crop planter, potato planter and digger, reaper, thresher, trolley, pump. Theses farmers have seen demonstrations of theses matching equipment either in the Himachal Pradesh Agricultural University, Palampur or at others farmers' field organized by the university officials. Nearly two-third of the respondents in both tehsils expressed that they gained knowledge about power tiller from the University. About 50% of the respondents expressed that they do not want to use any power tiller attachment except the rotavator. It was indicated that hitching of any matching equipment like planter, cultivator and trolley is not easy by detaching the rotavator from the power tiller. A total 100% of the farmers were of the view that some financial support in term of subsidy of 50-60% should be provided for the purchase of matching implements like thresher, seed drill/ planter and trolley.

Annual Use of Power Tiller

The average annual use of the power tillers varied from a minimum of 16 hours to a maximum of 447 hours in Palampur and 24 hours to 442 hours in Baijnath tehsils. It is clear from the **Fig. 2** that a maximum of 53% farmers of Palampur used power tiller for 200-300 hours annually where as in Baijnath tehsil, a maximum of 32% farmers used power tiller for 100-200 hours annually. Only 12% farmers in Palampur and 25% in Baijnath used power tiller more than 300 hours. Average annual working hours by the power tiller were only 207 hours and 198 hours in Palampur and Baijnath, respectively. This was due to topography of area which has small and irregular size of plots; more than one feet vertical interval between terraces and have all other difficulties associated with hilly fields. For a 13 hp power tiller, farmers reported 12-13 hours for rota-tilling operation to cover one ha of area. Usually farmers are in practice of completing the bed in two passes.

Custom Hiring

Majority of the farmers in both the tehsils (76% in Palampur and 81% in Baijnath) using power tiller on custom hiring. The average annual use of power tiller on hiring was 182 hours in both the tehsils. This is in addition to the use of machines on their own fields. However, the power tiller hiring in Rabi season (98-100 hours) was observed more than Kharif (82-84 hours). In Rabi season, the sowing of wheat starts in November and it lasts up to mid of January depending upon the rain. So, farmers get more chance to operate their power tiller in this season. Hiring of power tillers was mainly for the rototilling operations by 100% farmers of both tehsils. Some farmers use wheat thresher with power tiller on hiring. About 12-18% farmers run atta chakki (flour mills) with power tiller engine. The prevalent rate of hiring varied from Rs.200 to Rs.250 per hour (61 Rs. = 1$ US). Custom hiring of the power tillers was observed to be one of the additional sources of income for the owners of the medium and small land holding category of farmers.

Fuel Consumption of Power Tiller

All the 9.7 kW VST Shakti 130 DI Mitsubishi brand power tillers and 11 kW Kranti power tillers used in the region were powered by diesel engines only. Most of farmers in both tehsils using Mitsubishi power tillers (86%) reported that its fuel consumption ranged from 1 to 1.25 L/h. However, 10% reported fuel consumption in the range of 1.25-1.5 L/h and rest 4% farmers reported less than 1.0 L/h with machines less than two year old. The fuel consumption of about 1.5 L/h was reported by farmers using Kranti make power tillers.

Repair and Maintenance

In both the tehsils, majority of the farmers (82%) were of the opinion that they got the required spare parts and repair facility beyond 20-30 km. The main problems pointed out by the farmers of both the tehsils in operation and maintenance of the power tiller was the non-availability of spare parts and repair

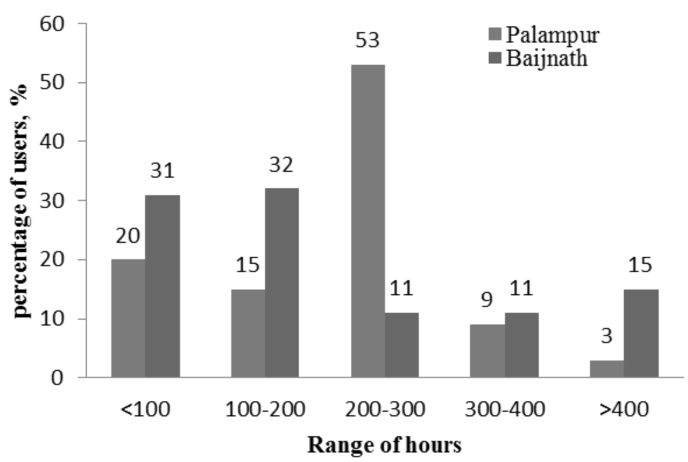

Fig. 2 Annual use of power tiller

facilities for timely repairs at nearby places in villages/block level. They had to rush to power tiller dealers at Maranda in Palampur and Chauntra in Baijnath for even very small spare parts like clutch wire and fan belt. Almost all the farmers were of the view that repair facilities (within 2-3 hours) were not available in the region. Due to lack of trained manpower and repair facilities at village level, some times during working season, power tiller remained idle for 2-3 days even for a minor problem that resulted in heavy loss to the farmers. Only three dealers were there in Palampur and Baijnath that catered the need of spare parts availability and repair facilities of all power tillers. Thus, farmers were forced to pay much higher prices for spare parts and repair charges due to lack of competition among the dealers/mechanics. Majority of the farmers were of the view that advance training on power tiller was necessary before its purchase on its proper operation and maintenance. Almost 60% power tiller owner had taken training in operation, minor repair and maintenance of power tiller by the Agricultural University, Palampur and rest of the famers wants to take this training.

Subsidy on Power Tillers

The information collected showed that 97% farmers in the Palampur and 96% in Baijnath tehsil were using the VST Shakti 130 DI make, 9.7 kW (13 hp) Mitsubishi brand power tiller. The reason for more Mitsubishi power tillers was due to its authorized dealership, availability of spare parts and maintenance facility in the region. In addition, the subsidy provided on this make by the state government and recommendations by the state agricultural university were other reasons for popularization of this power tiller in the state. The subsidy provided by the Government of Himachal Pradesh was Rs. 30,000 (≈ $492 US) per unit in 2002-03 and increased to Rs. 45,000 (≈ $738 US) in year 2009-10. It was observed that more and more farmers are coming forward to purchase power tiller.

Drudgery during Operation

The operator comfort or drudgery perceived during operation of machine is an important aspect in design. So, the information was collected on drudgery perceived in the use of power tiller operation for two different modes namely (1) for taking the power tiller to the field and (2) during operation of the machine in the field (**Table 5**). Majority of the farmers in both tehsils reported that power tiller transportation to the fields is very difficult. There was no approach roads to the fields in hills but had only very narrow pathways to transport power tiller to the fields. It was also pointed out that more than 80% fields had very small size (<50-80 m^2) with vertical interval in the range of 1.0-2.0 feet (30.5-61 cm). Farmers were facing a great difficulty in crossing the bunds from one field to another. Fifty percent of the farmers had ladder 3-4 feet (0.92-1.22 m) long made of angle iron or wood that they put under the wheels of power tiller while crossing the bunds/channel. The chances of overturning of power tiller while crossing the bunds was pointed by all the farmers. However, the operation of power tiller in the field was moderately difficult as pointed out by 52% farmers in Palampur and 56% in Baijnath tehsils. The turning of power tiller at head lands was difficult.

Data regarding opinion of user about power tiller was also collected, analyzed and presented in **Table 6**. Hundred percent of farmers in both tehsils were of the opinion that power tiller was economically viable source of power in hills which saved time and labour significantly, increased the land productivity and reduced drudgery. Majority of the owner pointed out it as a good

Table 5 Drudgery perceived during power tiller use in hills

Drudgery perceived	Number of farmers giving opinion, percent			
	Palampur tehsil		Baijnath tehsil	
	Transport	Operation	Transport	Operation
Easy	8	22	0	15
Moderately difficult	28	52	22	56
Difficult	64	24	78	29

Table 6 Opinion of user about power tiller

Opinion about power tiller	Percentage of farmers	
	Palampur	Baijnath
Liking of the operator	92	98
Economically viable source of power	100	100
Saving in time & labour substantially	100	100
Increase land productivity by 10-20%	85	86
Drudgery reduction (avoid clod breaking operation)	100	100
Within purchase capacity of farmers without subsidy	8	10
Financial help (subsidy) by Government	100	100
Good source of income on custom hiring	94	86
Respect in society as owing power tiller	100	100

Table 7 Opinions of farmers about power tiller and bullock drawn system

Power source	No. of operation	Time	Quality of work	Labour	Comfort
Power tiller	1-2 (less)	Less	Very good	Less	More
Bullock	3 (more)	More	Good	More	Less

source of income if used on custom hiring. Majority of the farmers had poor economic conditions and they showed their inability to purchase it if they do not get subsidy. However, only 8-10% farmers were able to purchase it without subsidy. All farmers agreed that they got the subsidy provided by the state government.

Farmers view about comparison of power tiller and bullock system showed that power tiller consumed less time to prepare a field in fewer passes then bullocks with more comfort (**Table 7**). Only one or two passes were required to prepare a field with power tiller where as it was two to three with bullocks. The area coverage with power tiller was reported in the range of 0.06-0.08 ha/h. The quality of work done by power tiller was also rated very good.

Limitations in Use

Power tiller use is limited to land preparation under dry and wet land conditions, sowing only for mixing the seeds and to some extent threshing and running flour mill (atta chakki) during off hours. The reasons stated by users for limited use of power tiller were

- The topography of the region
- Small size of field
- Vertical interval between terraces
- No approach roads to the fields
- Non-availability of suitable matching implements
- Non-availability of repair and maintenance facilities in nearby areas
- Weak financial conditions of the farmers
- Limited knowledge about matching implements
- Non-availability of skilled manpower for repair and maintenance
- Non-availability of genuine spare part like tines etc.

Conclusions

The following conclusions could be drawn from the study.

1. The majority of the small and marginal farmers (97.1% in Palampur and 88.5% in Baijnath) in hills of Himachal Pradesh own power tillers.
2. VST Shakti 130 DI power tiller was used by 97% of farmers in the Palampur and 96% in Baijnath tehsils and rest of 3 to 4% famers in both tehsil were using the other makes of power tiller.
3. The majority of the power tiller owners in both the tehsils (59% in Palampur and 81% in Baijnath) were self operator and had an average age of less than 40 years.
4. The average annual working hours of the power tillers were only 207 hours and 198 hours in Palampur and Baijnath, respectively whereas the average annual use on hiring was 182 hours in both the tehsils.
5. Every power tiller farmer (100%) in both the tehsils utilized it for rota-tilling i.e. field preparation in dry land conditions.
6. Majority of the farmers in both tehsils reported that transportation to the fields by power tiller was very difficult as there were no approach roads or pathways.
7. More than 80% fields had very small size (<50-80 m^2) with vertical interval of 1.0-2.0 feet (30.5-61cm).
8. Majority of the farmers (82%) were of the opinion that they got the required spare parts and repair facility beyond 20-30 km.

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Trend Analysis of Vegetation Indices Using Spectroradiometer at Different Growth Stages of Cotton

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Abstract

Remotely sensed spectral vegetation indices are widely used and have benefited numerous disciplines interested in the assessment of biomass, water use, plant stress, plant health and crop production. The successful use of these vegetative indices requires knowledge of the units of the input variables used to form the indices. Hyper spectral reflectance from cotton crop canopy was used to find indices like DVI, RVI, NDVI and TVI. The objective of study was to study the trend of temporal changes in vegetation indices at different growth stages. Spectral signatures of cotton crop were measured using tractor mounted spectroradiometer at different growth stages. Vegetation indices were calculated by using reflectance at R650 in red region and R770 in near infrared region. Results revealed that maximum DVI and TVI value was observed at boll opening stage and boll filling stage respectively. After peak flowering stage RVI, NDVI and SAVI values shows linear trend.

Keywords: Cotton, Spectroradiometer, Vegetation Indices, DVI, RVI, NDVI, RDVI, SAVI and TVI etc.

Abbreviations

DVI	Difference Vegetation Index
RVI	Ratio Vegetation Index
NDVI	Normalized Difference Vegetation Index
RDVI	Renormalized Difference Vegetation Index
SAVI	Soil Adjusted Vegetation Index
TVI	Transformed Vegetation Index
NIR	Near-Infrared

Introduction

Spectral signatures of body depend upon electromagnetic radiations emitted from object. For assessment of plant health, biomass, crop production and water use the spectral signatures of crop canopy use to estimate the vegetation indices. In healthy crop canopy spectrum is absorbed in visible region and at same time spectrum is reflected in near infrared region. The successful use of these vegetative indices requires knowledge of the units of the input variables used to form the indices and an understanding of the manner in which the external environment and the architectural aspects of a vegetation canopy influence and alter the computed index values (Jackson and Huete 1991).

At different growth stages of cotton crop canopy hyper spectral remote sensing detect the characteristic difference during its growing season (Zhao *et al* 2004). Difference Vegetation Index (DVI), Ratio

Vegetation Index (RVI), Normalized Difference Vegetation Index (NDVI), and Renormalized Difference Vegetation Index (RDVI) calculated by using hyper spectral reflectance from cotton crop canopy used to differentiate crop canopy (Zhao *et al.*, 2005 and Zhao *et al.*, 2007). Remotely sensed data have been widely used to develop vegetation indices as indicators of crop growth, nutrient status and yield development. Studies suggest that crop spectral reflectance can be used to detect abiotic and biotic environmental stresses in plants (Filella *et al.*, 1995 and Osborne *et al.*, 2002).

When a light is striking on any surface then part of light is reflected, transmitted and absorbed. The amount of reflection, transmission and absorption depends on surface and wavelength of light. For plants near infrared wavelength is reflected and transmitted with small absorption. But in visible wavelength is absorbed with little reflection and transmission of light. Most of times sunlight is used as the source of light to capture spectral signatures of crop. Irradiance of sunlight changes with time and atmospheric conditions. So, only reflection is not suitable to characterize the crop. Hence, the problem is solved by combining the two or more spectral wave bands known as vegetation indices. Vegetation indices calculated from sensor output voltage, radiance value, and reflectance value and satellite digital numbers. The objective of study was to study the trend of temporal changes in vegetation indices at different growth stages.

Fig. 1 View of capturing of spectral signatures of cotton crop

Table 1 Dates of capturing of spectral signatures

Date	Growth stages (DAS)
30 May, 2014	Node formation (21)
10 June, 2014	First Squaring (31)
20 June, 2014	Squaring (41)
30 June, 2014	Early flowering (51)
10 July, 2014	Mid flowering (61)
20 July, 2014	Peak flowering (71)
30 July, 2014	Boll formation (81)
09 August, 2014	Boll filling (91)
19 August, 2014	Boll opening (101)

Materials and Methods

Location and Cultural Practice

The field experiment was conducted during *kharif* 2014 at the experimental farm Department of soil science, Punjab Agricultural University, Ludhiana, Punjab, India at 30°56' N latitude and 75°52' E longitude with a mean height of 247 meter above the mean sea level The field experiment was designed in split plot design with two cultivars (ANKUR 3028 BG- II and RCH 650) in main plots and seven N fertilizer applications [0 (T_1), 30 (T_2), 60 (T_3), 75 (T_4), 90 (T_5), 120 (T_6) and 150 (T_7) N kg/ha] treatments in sub plots with three replications. Total 42 plots of size 9 × 2.7 (24.3 m^2) were sown at row to row spacing of 60 cm and plant to plant spacing of 67.5 cm.

Tractor Mounted Spectroradiometer

A 512—channel ASD Fieldspec® Pro 2000 Specroradiometer (Analytical Spectral Device Inc., Boulder, CO, USA) with range 350-2,500 nm was mounted on developed frame mounted on high clearance John Deere tractor (**Fig. 1**). A Spectralon white reference panel was used to optimize the instrument to 100% reflectance at all wavebands prior to canopy reflectance measurement. Canopy spectra from cotton were measured at 11:00-14:00 hours ignoring sharp 12.00 noon under cloudless and windless weather condition. Reflectance measurement was made about 1 m above canopy throughout the growing season starting from squaring stage at 10 days interval. Sensor facing the crop and oriented normal to plant using 25° field of view (FOV) and 5 spectral reflectance measurements was used as the reflectance from each plot. During the reflectance measurement tractor was in steady state. The number counted as soon

Table 2 Vegetation indices

Acronym	Name	Formula	Author	Description
DVI	Difference vegetation index	$DVI = R_{NIR} - R_{Red}$	Jordan (1969)	Zero value of DVI indicate bare soil, negative value indicate water and positive value indicate vegetation
RVI	Ratio vegetation index	$RVI = R_{NIR}/R_{Red}$	Pearson and Miller (1972)	Used to minimize topography effect.
NDVI	Normalized vegetation index	$NDVI = R_{NIR} - R_{Red} / R_{NIR} + R_{Red}$	Rouse *et al.* (1974)	It minimize topographic effect when use as linear scale for measurement of vegetation
SAVI	Soil adjusted vegetation index	SAVI = NDVI × (0.5 + L)	Huete (1988)	Minimize the effect of soil background on vegetation signal
TVI	Transformed vegetation index	$TVI = \sqrt{NDVI} + 0.5$	Deering *et al.* (1975)	0.5 order is introduced to avoid the problem with negative value of NDVI

as reflectance measurements were made.

Collection of Spectral Signatures

Spectral properties of cotton crop were measured using tractor mounted Specroradiometer. Spectral properties were measured at 10 days interval starting from squaring stage i.e. 41 days after sowing (DAS) stage to boll opening stage i.e. 101 DAS. During the reflectance measurement tractor was in steady state. The number counted as soon as reflectance measurements were made.

Calculations of Vegetation Indices

Spectroradiometer was used to measure the reflectance of five randomly selected plants in each plot during various growth stages of cotton crop. Average reflectance of five plants recorded at each wavelength from 350 nm to 2,500 nm. Vegetation indices were calculated by using spectral reflectance at R650 in red region and R750 in region described in **Table 2**.

Statistical Analysis

An analysis of variance (ANOVA) was performed to test N effects on different vegetation indices at different growth stages of cotton crop. Mean separation was determined using LSD at a P = 0.05. Analyses were performed using Crop stat.

Results and Discussion

The average DVI values for the two cultivars and fertilizer N application were plotted against the different growth stages in (**Fig. 2 A**). The data revealed that maximum DVI value was observed at boll opening stage of cotton crop and graph shows that increasing trend. At early flowering and boll opening stage shows same DVI value.

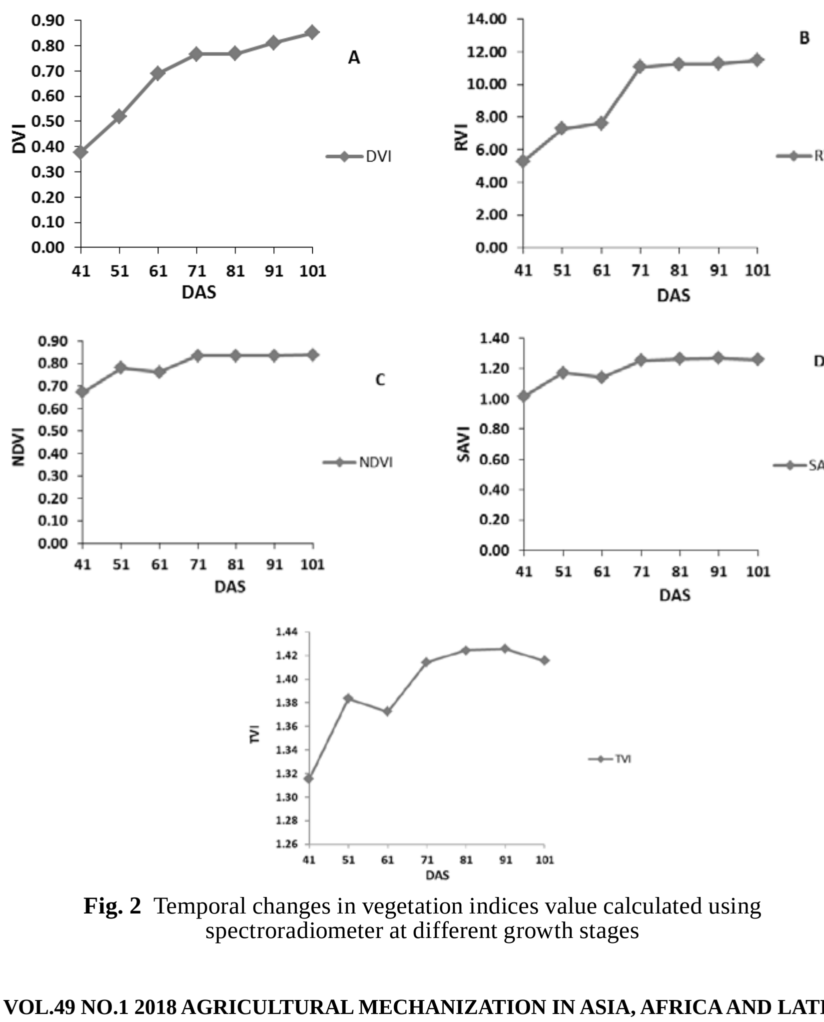

Fig. 2 Temporal changes in vegetation indices value calculated using spectroradiometer at different growth stages

The RVI readings of cotton crop shows increasing trend from early squaring stage to boll opening stage. Data revealed that from mid flowering stage to peak flowering stage there was suddenly increase in RVI value and from peak flowering to boll opening stage data shows the no variation RVI values. Maximum and minimum value of RVI observed at squaring stage and boll opening respectively (**Fig. 2 B**).

The average NDVI values for the two cultivars and fertilizer N application were plotted against the different growth stages in (**Fig. 2 C**). NDVI value shows increasing trend from squaring stage to peak flowering stage. Towards the maturity from peak flowering stage to boll opening stage value of NDVI shows linear trend. The increasing NDVI values with the growth of the crop indicated increase in biomass of the crop with time.

The SAVI readings showed similar trend as NDVI value with the growth of the cotton crop (**Fig. 2 D**). Initially at squaring stage minimum value of SAVI observed. After mid flowering stage increase in value and from peak flowering to ball opening stage SAVI value become constant.

The average TVI values for the two cultivars and fertilizer N application were plotted against the different growth stages in (**Fig. 2 E**). As other vegetation indices TVI value also shows the increasing trend with different growth stages. Maximum value of TVI was observed at boll filling stage. Towards the maturity at boll opening stage decrease in value of TVI was observed.

Conclusions

Temporal change in vegetation

index at 0 N kg/ha (control) shows similar trend as 30, 60, 75, 90, 120 and 150 N kg/ha. At initial growth stages increase in values of vegetation values but towards maturity it will become steady or decline.

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■■

Research on a Method to Measure and Calculate Tillage Resistance of Tractor Mounted Plough

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Abstract

In the existing electro hydraulics hitch control system of tractors, the measuring method of the tillage resistance can not accurately reflect the tillage resistance of the mounted plough. Analysis of the measurement method of the tillage resistance is carried and a method of is proposed to measure the tillage resistance of mounted plough by the force signal of hinge points of the upper link and lower link. The solving matrix of tillage resistance is established by using the principle of space vector force mechanics. A resistance measurement system prototype is developed on the JINMA 1204 tractor. The ill-condition of the solving matrix is analyzed, and the calculate program of the tillage resistance is developed. Field tests of tillage resistance measuring system were carried out. The test results show that the correlation coefficient between measured value and test value of tillage resistance measurement system is 0.79, which belongs to strong correlation and shows that the tillage resistance method proposed in this paper is effective. Through the calibration of the resistance measurement system, the maximum reference error between the measured value of the tillage resistance and the resistance test value of the tillage is 5.7%, which can meet the measurement requirements of the electro hydraulics hitch control of agricultural tractor.

Key words: Agricultural tractor; Mounted plow; Tillage resistance; Measurement method

Introduction

In electro hydraulics hitch control of agricultural tractor, the tillage resistance signal provides the work load information for draught control algorithm and draught-position mix control algorithm[1], therefore, the measurement of tillage resistance is very important. In the electro hydraulics hitch control of tractor proposed[2-3], the force sensor is usually installed at the hinge point of the lower link and the tractor body, and the tillage resistance is achieved by the force signal at the hinge point of the lower link. Because the mounted plow is connected with the tractor through an upper link and two lower links, the force signal at the hinge point of the lower links can not accurately reflect the tillage resistance of the plough; therefore, the research on the measurement of tillage resistance of the mounted plow is of great significance to the electric hydraulics hitch control of tractors.In the field of measuring the tillage resistance, some researchers have put forward many measuring schemes for the tillage resistance, and obtained better results. The proposed measurement methods can be divided

Nomenclature

$\mathbf{A_i}$	force vectors of point in the A_i lower link
$\mathbf{T_i}$	force vector of point T_i in the lower link
$\mathbf{F_i}$	the force vector of point B_i in the lower link.
F_i	the length of force vector $\boldsymbol{F_i}$
$\mathbf{A_iB_i}$	the geometric vector of A_iB_i
$\mathbf{A_iT_i}$	the geometric vector of A_iT_i
F_t	the test value of the tillage resistance
$F_d\,(i)$	the sample value of the tension sensor
R	the acting point of tillage force
$\mathbf{R}$	the force vector of point R
$\mathbf{K}$	the force vector of the hang point of the upper link,
K	the length of force vector $\mathbf{K}$
$\mathbf{DK}$	the geometry vector of DK
$\mathbf{DR}$	the geometry vector of DR
$\mathbf{DW}$	the geometry vector of DW
$\mathbf{DT_1}$	the geometry vector of DT_1
$\mathbf{DT_2}$	the geometry vector of DT_2
$R_y\,(i)$	the sample measuring value of the tillage resistance
F_d	traction force value of prototype
f	the rolling resistance of the prototype

into three types. The first method is measured by installing a strain beam or force sensor on the plow body[4-5], The method has higher measurement accuracy and is often used to evaluate the mechanical properties of a single plough. The second method is to install sensors or measuring devices between hitch mechanisms and the farm implements, which are often used to evaluate the overall mechanical performance of ploughs. For traction farm tools, the force sensor is installed between the tractor drawbar and the farm implements[6], and the tillage resistance is measured directly; For the mounted plough, the measuring frame designed is connected between the tractor hitch mechanism and the plough. The load of the mounted plough is measured by strain beam[7] or force sensor [8-11] on the measuring frame, however, the measuring frame changes the installation position of the tractor and plough, which can not fully reflect the actual working conditions of the tractor plough set. The third method is to integrate force sensors into hitch links[12-13], calculate the plow tillage resistance is calculated by hitch link force signal and plow position signal; This method can fully reflect the actual working conditions of the tractor mounted plow and is used to evaluate the overall mechanical properties of plow. However, in the electro hydraulics hitch control of tractors, In electro hydraulics hitch control of tractors, it is necessary to install sensors with simple, low cost and easy to popularize the measuring method of tillage resistance on tractor. The above three methods are often used in experimental research, the first method need to install sensors in the plough body and increased the structure complexity and cost of the plough body; The second method is to add a measuring frame to tractors and ploughs, the third approach involves integrating multi-dimensional sensors into hitch links, which increases the complexity and cost of dangling links similarly. Thus, above three methods are not suitable for extension of the electro hydraulics hitch control of the tractor. Therefore, it is of great significance to study the tillage resistance measurement scheme of small change and convenient installation of sensors in application of electro hydraulic hitch control technology. This paper adopts the force of upper link and lower links hinge point to measurement of the tillage resistance. As hinge points of links and the body is fixed, the sensor installation is convenient without changing the hitch structure and plow structure, which can be applied in the electro hydraulic hitch control of tractor.

Material and Methods

Measuring Scheme of Tillage Resistance of Mounted Plough

Considering the simplicity of sensor installation, a method for measuring the tillage resistance is presented by using force signals at the hinge joint of the upper link, the lower link and position signals. The measurement scheme is shown in **Fig. 1**. Two shaft force sensors are used to replace the jointed shafts between lower links and the tractor, and the horizontal component force signal of the lower link hinge joint is obtained; A shaft force sensor is used to replace the jointed shafts between the upper link and the tractor, and the force signal of the upper link hinge joint is also obtained, the direction of the force signal is the same as the upper link.

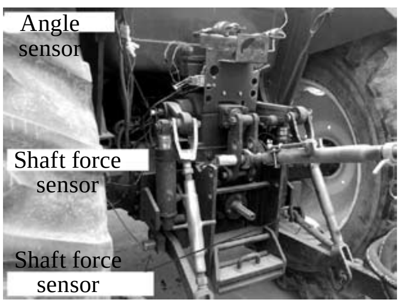

Fig. 1 Instrument of tractor three-point hitch mechanism

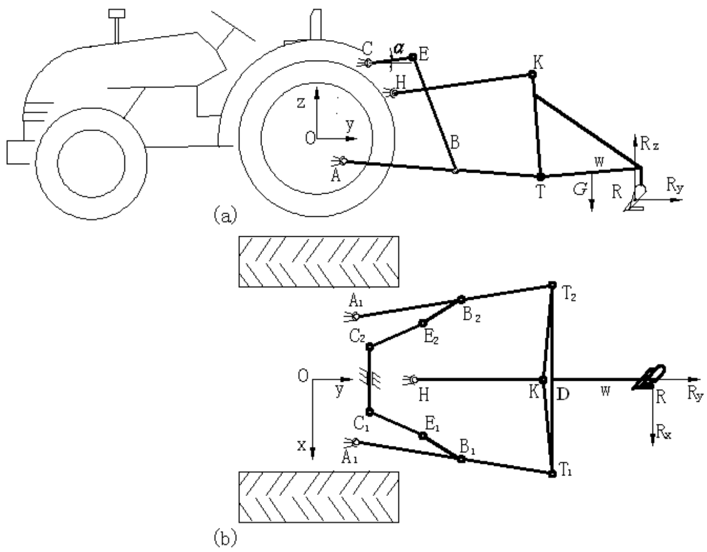

Fig. 2 Side view
(a) and upper view (b) of the three-point hitch mechanism showing lower link 1; Lifting link 2 and its length is $l = BE$; Lifting arm 3 and its angle position is α; Upper link 4; Mounted plough 5 and R is acting point of tillage force; The hinge joint of lower link A; Hinge joint of upper link H; Hinge joint of lifting arm C; Upper hitch point of plough K; Lower hitch point T; The midpoint of lower hitch points D; Longitudinal component of tillage force R_y; Lateral component of tillage R_x; Vertical component of tillage force R_z: Gravity center of the mounted plough W and gravity is G.

An angle sensor is used to measure the angular position of the lift arm. Because each lower link has three force acting points, the tillage resistance of the farm implements cannot be obtained directly by force signal of these shaft sensors. Thus, it is necessary to establish solving model of tillage resistance based on the position of three-point hitch and force signal of these shaft sensors. In the analysis, it is approximately assumed that the right lower link and left lower link are symmetrical about the longitudinal centerline of the tractor during plowing [13], thus, the position of the three-point hitch and the position of the farm tool can be solved by the position angle of the lifting arm. The action point of the tillage resistance is located in the middle plough body or imaginary middle plough body position in longitudinal direction. According to the distribution characteristics of soil resistance in the plough [14], the seam line of ploughshare edge line and plough surface is assumed action location of tillage resistance on plough body in vertical direction.

The Tillage Force Solving Model of Mounted Plough

The running speed of tractor, depth of tillage and physical properties of soil will influence the resistance of plough in tillage process [15]. Considering the general condition of stable speed of tractor cultivation, the agronomy requirement for tillage uniformity and similar physical properties of soil in the same field, hence, the tillage resistance of plough is dominated by steady force. It is feasible to analyze the tillage force of the mounted plough with vector mechanics. For the convenience of analysis, the coordinate system O-XYZ is established with the midpoint of the rear axle of the tractor as the origin, as shown in **Fig. 2**.

The lower link in **Fig. 2** (i = 1 as the left lower link, i = 2 as the right lower link) is taken as the study object, and the equilibrium equations of force vectors are established as follows:

$\boldsymbol{A_i} + \boldsymbol{F_i} + \boldsymbol{T_i} = 0$ ....(1)

Where

$\boldsymbol{A_i} = [A_{ix}, A_{iy}, A_{iz}]$

$\boldsymbol{T_i} = [T_{ix}, T_{iy}, T_{iz}]$

The directional cosine of $\mathbf{F_i}$ is $[B_{ia}, B_{i\beta}, B_{i\gamma}]$; The geometric vector of $B_i E_i$ is $[x_{BEi}, y_{BEi}, z_{BEi}]$; Thus, $B_{ia} = x_{BEi} / l$, $B_{i\beta} = y_{BEi} / l$, $B_{i\gamma} = z_{BEi} / l$

According to the torque of $\mathbf{F_i}$ and $\mathbf{T_i}$ to the point A_i, the moment balance equation of the lower link is obtained:

$\boldsymbol{F_i} \times \boldsymbol{A_i B_i} + \boldsymbol{T_i} \times \boldsymbol{A_i T_i} = 0$ ....(2)

Where $\mathbf{A_i B_i} = [x_{ABi}, y_{AB}, z_{ABi}]$, $\mathbf{A_i T_i} = [x_{ATi}, y_{ATi}, z_{ATi}]$; According to (1) and (2), the linear independent equations can be written as following:

$A_{ix} + F_i \cdot B_{ia} + T_{ix} = 0$ ....(3)

$A_{iy} + F_i \cdot B_{ib} + T_{iy} = 0$ ....(4)

$A_{iz} + F_i \cdot B_{i\gamma} + T_{iz} = 0$ ....(5)

$T_{iy} \cdot z_{ATi} - T_{iz} \cdot y_{ATi} + F_i \cdot B_{i\beta\gamma} = 0$ .....(6)

$T_{ix} \cdot y_{ATi} - T_{iy} \cdot x_{ATi} + F_i \cdot B_{i\alpha\beta} = 0$ ..(7)

Where,

$B_{i\beta\gamma} = z_{ABi} \cdot B_{i\beta} - y_{ABi} \cdot B_{i\gamma}$,

$B_{i\alpha\beta} = y_{ABi} B_{i\alpha} - x_{ABi} \cdot B_{i\beta}$

Since the A_{iy} can be measured by the shaft sensor in the hinge joint of the lower link, the unknown parameter is A_{ix}, A_{iz}, F_i, T_{ix} T_{iy} and T_{iz} in Formula 3 to formula 7. When $i = 1$, 2, there are 10 equations that contain 12 unknown parameters.

As shown in **Fig. 2**, $\mathbf{R} = [R_x, R_y, R_z]$; The directional cosine of $\mathbf{K}$ is written as $[K_\alpha, K_\beta, K_\gamma]$. When the plough is taken as the study object, the force vector of the hang point of the plough is opposite to the force vector of the hang point T_i of the upper link; The equation of force balance for the plough is established as follows:

$-T_{1x} - T_{2x} + K \cdot k_\alpha + R_x = 0$ ....(8)

$-T_{1y} - T_{2y} + K \cdot k_\beta$; $R_y = 0$ ....(9)

$-T_{1z} - T_{2z} + K \cdot k_\gamma - G + R_z = 0$ ....(10)

As shown in **Fig. 2**,

$\boldsymbol{DK} = [x_{DK}, y_{DK}, z_{DK}]$

$\boldsymbol{DR} = [x_{DR}, y_{DR}, z_{DR}]$

$\boldsymbol{DW} = [x_{DW}, y_{DW}, z_{DW}]$

$\boldsymbol{DT_1} = [x_{DT1}, y_{DT1}, z_{DT1}]$

$\boldsymbol{DT_2} = [x_{DT2}, y_{DT2}, z_{DT2}]$

The torque balance equation of the D point on the plow is as follows:

$\boldsymbol{K} \times \boldsymbol{TK} + \boldsymbol{R} \times \boldsymbol{DR} - \boldsymbol{T_1} \times \boldsymbol{DT_1} - \boldsymbol{T_2} \times \boldsymbol{DT_2}$ ....(11)

Because the left lower link and right lower link are symmetrical about the longitudinal center line of the tractor, according to the equation (11), write the equation are written as follows:

$K \cdot k_\beta \cdot z_{Tk} - K \cdot k_\gamma \cdot y_{DK} + R_y \cdot z_{DR} - R_z \cdot y_{DR} + G \cdot y_{DW} = 0$ ....(12)

$K \cdot k_a \cdot y_{DK} - K \cdot k_\beta \cdot x_{DK} + R_x \cdot y_{DR} + T_{1y} \cdot x_{DT1} + T_{2y} \cdot x_{DT2} = 0$ ....(13)

From (8) to (13), the K can be measured by the shaft force sensor of the upper link and the unknown parameter is T_{ix}, T_{iy}, T_{iz}, R_x, R_y and R_z. Therefore, the system of equations containing 15 equations comes from (3) to (13), and the number of unknown parameters is 15. The equations are written in the form of matrices as follows:

$\boldsymbol{A} \cdot \boldsymbol{X} = \boldsymbol{b}$ ....(14)

Where $\mathbf{A}$ is the coefficient matrix, and ;

$$\mathbf{A} = \begin{bmatrix} \mathbf{R}_1 & \mathbf{R}_3 \\ \mathbf{R}_2 & \mathbf{R}_4 \end{bmatrix}$$

$$R_1 = \begin{bmatrix} 1 & 0 & B_{1\alpha} & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & B_{1\beta} & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & B_{1\gamma} & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & B_{1\beta\gamma} & 0 & z_{AT1} & -y_{AT1} & 0 & 0 \\ 0 & 0 & B_{1\alpha\beta} & y_{AT1} & -x_{AT1} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$R_2 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & x_{TT1} & 0 & 0 & 0 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ B_{2\alpha} & 1 & 0 & 0 & 0 & 0 & 0 \\ B_{2\beta} & 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$R_s = \begin{bmatrix} B_{2y} & 0 & 1 & 0 & 0 & 0 & 0 \\ B_{2\beta} & 0 & z_{AT2} & -y_{AT2} & 0 & 0 & 0 \\ B_{2\alpha\beta} & y_{AT2} & -x_{AT2} & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & z_{ZR} & -y_{ZR} \\ 0 & 0 & x_{ZT2} & 0 & y_{ZR} & 0 & 0 \end{bmatrix}$$

$\mathbf{X} = [A_{1x}\ A_{1z}\ F_1\ T_{1x}\ T_{1y}\ T_{1z}\ A_{2x}\ A_{2z}\ F_2\ T_{2x}\ T_{2y}\ T_{2z}\ R_x\ R_y\ R_z]^T$

$\mathbf{b} = [0\ \text{-}A_{1y}\ 0\ 0\ 0\ 0\ \text{-}A_{2y}\ 0\ 0\ 0\ \text{-}K \cdot k_a\ \text{-}K \cdot k_\beta\ b_{13}\ b_{14}\ b_{15}]^T$

Where

$b_{13} = G - K \cdot k_\gamma$

$b_{14} = K(k_\gamma \cdot y_{DK} - k_\beta \cdot z_{DK}) - G \cdot y_{DW}$

$b_{15} = K(k_\beta \cdot z_{DK} - k_a \cdot y_{DK})$

Formula (14) is a model for solving the tillage resistance of the mounted plough. The coordinate of the hitch mechanism is calculated by the position angle of the lifting arm and the coefficient matrix **A** is derived. The A_{1y}, A_{2y} and K can be measured by the shaft force sensors, thus, vector **b** can also be solved by signal of force sensors and position coordinates of hitch mechanism. Formula (14) can be transformed as:

$\mathbf{X} = \mathbf{A}^{-1} \cdot \mathbf{b}$ ....(15)

Where **X** is solved and the tillage resistance R_y was obtained. Because the inversion of matrix **A** has a larger amount of computation, the tillage resistance R_y can also be solved directly from the formula (14) by the Cramer's rule that can reduce the computational complexity.

Establishment of Measuring System Prototype

A JM1204 (power 88 kW) wheeled tractor is used as a platform to build a prototype for measuring the tillage resistance, and the type of plough adopts hydraulic reverse mounted plough (1DF435). The sensor is installed according to the measurement scheme of tillage resistance.

In the hitch mechanism of JM1204 tractor, a shaft force sensor (range:-10KN~25KN, linear precision: + 0.5%, BCM company) connects the upper link and tractor, the direction of the measuring force is consistent with the direction of the upper link by a limiting device. Two pin shaft force sensors (range -30KN~30KN, linear accuracy + 0.5%, BCM company) connects the lower links and tractor, and the direction of the force measurement is horizontal by the limiting device. A non-contact angle sensor (measuring 0-200 degrees, linear accuracy + 0.3%, WDA-DP40, Miran) is mounted to measure the angle position of the lifting arm. The data is acquired by a microcontroller (MC050, Sauer, Danfoss, sampling frequency: 0~1,000 kHz) that supports Plus+ software (Sauer, Danfoss). Due to the plough resistance is given priority to with steady-state forces, the sampling frequency is set to 10 hz, and the force signal filtering by average filter. The PC communicates with the microcontroller through the CAN-UBS data line and record the data.

In the prototype, the coordinate parameters of the connection point between the hitch mechanism and the tractor are shown in **Table 1**, and the structural parameters of the hitch mechanism and the mounted plough are shown in **Table 2**.

According to the tillage resistance model (14) and the solution method (15), the calculation program is edited in the Matlab (R2010) software environment and the program flow is shown in **Fig. 3**. The calculation program included two subroutines, the calculation result of the first sub-routine (CP1) is the coordinate of the hitch mechanism and the calculation result of the second subroutine (CP2) is tillage resistance of the mounted plough.

Results and Discussion

In the resistance measurement system, some factors will lead to errors in measurement and calculation. In calculation program, the point of resistance application on the plough is a fixed position. In fact, with the change of tillage depth, the position of the resistance application will be changed. Secondly, the position calculation error of hitch mechanism is caused by the joint clearance of the hitch mechanism. Finally, the sensor's signal error is also the source of measurement error. Therefore, it is necessary to test and calibrate the resistance measurement prototype system to improve the accuracy of the measurement of tillage resistance

Table 1 Coordinate value of hinge joints on tractor (unit: mm)

		Hinge				
		H	A1	A2	C1	C2
Tangent point	x	0	350	-350	150	-150
	y	580	100	100	265	265
	z	380	-250	-250	425	425

Table 2 Structure parameters of the hitch-mechanism and plough (unit: mm)

HK	AT	HK	CE	AB	KD	T_1T_2
780	1100	780	286	670	680	1100

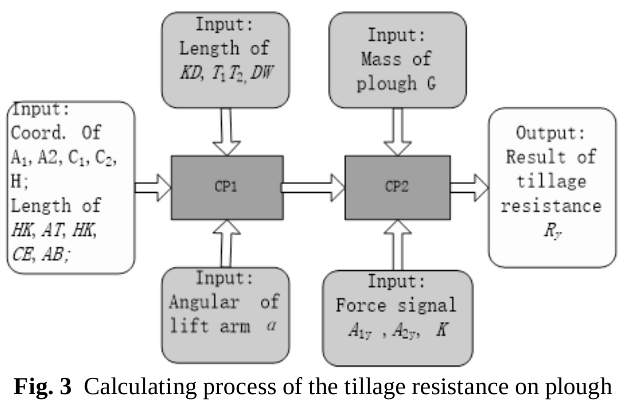

Fig. 3 Calculating process of the tillage resistance on plough

Field Test on Measurement System Prototype

The test scheme of tillage resistance measurement is referred to the field traction performance test method of tractors [16-17]. A truck tractor (JM 1304, Power 95.5kW) was used to drag the prototype for cultivation, and accurate measurements of tillage resistance were obtained. The specific scheme is shown in **Fig. 4**, a tractor drag the prototype with the tillage resistance measurement system by a drawbar and a tension sensor (measurement range: 0~100 kN). In the test, the transmission lever of the prototype is in neutral. The signal of the traction sensor is collected by a microcontroller in the prototype with the measurement system.

Because the tillage resistance is directly proportional to the tillage depth, the tillage resistance load of the prototype can be achieved by setting the depth of tillage. The test consisted of multiple traction distances, each of which kept the same tillage depth that can be controlled by position adjustment model from the prototype. Each traction distance is not less than 30 meters, and the traction speed is about 3 km / h. When the tillage depth reaches the set value, the resistance measuring value $R_y\ (i)$ of the measuring system and the traction force value $F_d\ (i)$ of the tension sensor are recorded, and the i is the sampling sequence in the test.

For each traction distance, the tillage resistance measuring value of measurement system can be written as:

$$R_y = \frac{1}{n}\sum_{i=1}^{n} R_y(i) \quad ....(16)$$

The traction force value of measurement system prototype can be written as:

$$F_d = \frac{1}{n}\sum_{i=1}^{n} F_d(\mathrm{i}) \quad ......(17)$$

Since traction force includes the rolling resistance of the prototype and the tillage resistance, traction force of each traction distance can be written as:

$$F_d = f + F_t \quad ....(18)$$

Where f is the rolling resistance of the prototype; and F_t is the test value of the tillage resistance. When the tillage depth of the test distance is set to 0, in other words, the mounted plough is not tilled, $F_t = 0$ The rolling resistance of the measuring prototype can be obtained by this test: $f = F_d$. Therefore, a test value of tillage resistance can be obtained in the test distance that the depth setting is not zero:

$$F_i = F_d - f \quad ....(19)$$

Analysis of Test Results

The rolling resistance test curve of the prototype is shown in **Fig. 5**. It shows that the rolling resistance of the prototype is fluctuating, and the reason is the unevenness in the field. The maximum value of rolling resistance is 4.21 kN and the minimum is 3.52 kN. The average value of rolling resistance is 3.90 kN.

According to the test values of the tillage resistance and the measured values of the prototype in different tillage depths, a scatter diagram is drawn and the reference error curve of the measured value of the prototype is drawn by taking the test value as the reference of the tillage resistance. **Fig. 6** shows that there is a clear deviation between the measured values of tillage resistance and the test values. The fiducial error is greater while the tillage depth is small, and the maximum fiducial error reaches 21.7%. The fiducial error is minimum while tillage depth reaches 300 mm. This shows that the influence of error sources on the measurement system is larger in shallow tillage conditions than in deep tillage condition.

Furthermore, correlation analysis between measurement value R_y and test value F_t is carried out by correlation function in Excel. The correlation between the measured value and the test value is 0.98, and the two belong to strong correlation. The measured values R_y can reflect the change trend with the test value F_t. This shows that the formula (14) of calculation model of tillage resistance is correct.

Calibration of Measurement Systems

Through the above test and analysis, the measurement system has a great error in measuring the tillage resistance. However, considering the high correlation between the measured value and the experimental test value, it is possible to improve its accuracy by calibrating tillage resistance measurement system. The measured values of tillage resistance were fitted by the Matlab software cftool toolbox, and the fitting equation was as follows:

$$y = 0.8894 \cdot R_y + 5.2919 \quad ....(16)$$

Where y is the calibration value of the resistance measuring value R_y.

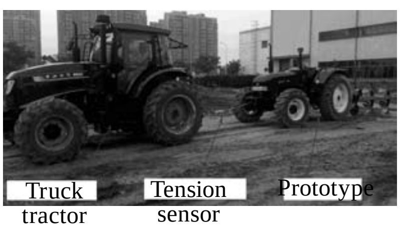

Fig. 4 Measurement schemes of tillage resistance

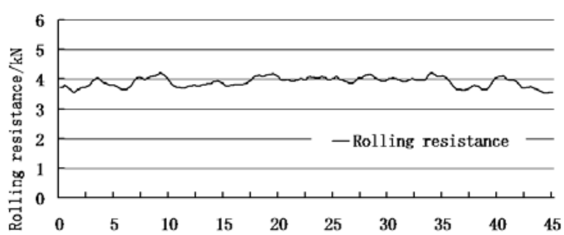

Fig. 5 Rolling resistance of the measurement prototype

According to formula (16), the calibration curve of the measured values of tillage resistance in tillage experiments was plotted (**Fig. 7**). The fiducial error curve of the calibration value is plotted for reference to the resistance test value F_t. The maximum fiducial error is 5.7%, which indicates that the accuracy of the resistance measurement is improved by the calibration resistance measurement system.

Conclusions

According to the requirement of electro hydraulics hitch control of agricultural tractor in measure the tillage resistance of the mounted plough, the measuring scheme of the tillage resistance of the hanging plough is analyzed. A scheme for measuring tillage resistance is proposed by using the force signal of joints between hitch mechanism and tractor. The scheme has small change to the hitch mechanism, and the sensor is easy to install. It is suitable for the electric control farming system. A mathematical model for calculating tillage resistance is established and a computer program is developed. Field tests of tillage resistance were carried out on the tillage resistance measuring system of the prototype. The test results show that there is an obvious deviation between the measured values of tillage resistance and the test values. However, the correlation coefficient between measured value and test value of tillage resistance measurement system is 0.79, which belongs to strong correlation and shows that the measurement method of mounted plough proposed in this paper is effective. Through the calibration of the resistance measurement system, the maximum reference error between the resistance value of the tillage resistance and the resistance test value of the tillage unit is 5.7%, which can meet the measurement requirements of the electro hydraulics hitch control of agricultural tractor.

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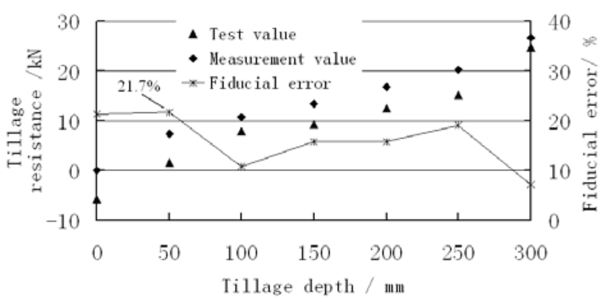

Fig. 6 Measurement value and calculated vale of tillage resistance force

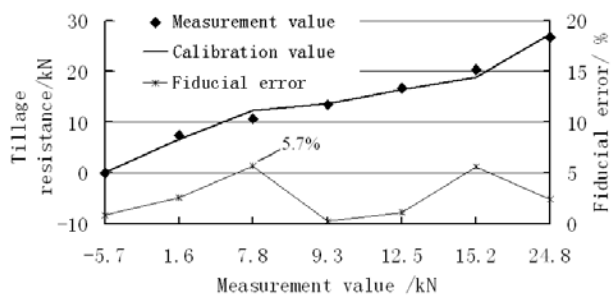

Fig. 7 Calibration of the resistance measuring prototype

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Outline to the Ukrainian Market of Agricultural Tractors in 2016

by

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Abstract

This paper outlines the current situation that occurred in the Ukrainian domestic market of agricultural tractors in 2016. The total available number of the tractors and their locations in Ukrainian districts is described here. The dynamics represented by years in order to represent the general market's capacity. Some general tendencies and facts have also been discussed. And further, the information was gathered on the quantitative sales of new tractors by years and brands to show the preferences, trends and overall paying capacity of Ukrainian agrarian enterprises. There prices for new tractors in Ukraine in 2016 can also be found. All the Tables and Figures are based on the statistical data provided by the State Statistics Service of Ukraine and the State Fiscal Service of Ukraine.

Key words: tractors, statistics, agricultural enterprises, sales, tendencies

Introduction

Ukraine through its history had a well-developed agriculture. In 2016 the acreage under agricultural crops exceeded 27 million hectares. Ukraine is actively involved in global export of food and other agricultural products. Agricultural businesses widely use the intensive agricultural production and they clearly understand the value of good machines including their efficiencies.

Ukraine has good traditions in manufacturing of agricultural machinery, however the level of competition is very high. Today's offers on the market of agricultural machinery in Ukraine widely range from the second-hand to the world-best new machinery.

General Overviews

The State Statistics Service of Ukraine says there were 339,829 tractors in Ukraine in 2016. Of these, agricultural enterprises owned 132,686 tractors (39% from total) and private households owned 207,143 tractors (The State Statistics Service of Ukraine, 2017).

In Ukraine, about 24.6% of rural households own tractors (The State Statistics Service of Ukraine, 2017). According to legislation these private rural households need not to report how they use this machinery and information about the technical conditions of these tractors is unavailable.

All the next data were collected by the State Fiscal Service of Ukraine from agricultural enterprises that belong to following criteria. The enterprise owns at least 200 hectares of agricultural land, or has more than 50 heads of cattle, or more than 500 heads of poultry (in the reported year), or gain the net income over 150 thousand UAH (approx. 5,868 USD), or the number of employees was over 20 persons (for the previous to the reporting year). **Fig. 1** represents the total number of tractors owned by agricultural enterprises in Ukraine.

The **Fig. 1** shows that enterprises owned 318.9 thousand tractors in 2000, and they have 132.7 thousand in 2016. The most of these 200 thousand tractors, that owned by the rural households, are second-hand machinery after Ukrainian agricultural enterprises.

The disadvantage of statistical reports is that the data includes all the tractors registered on a balance of companies. The reports include leased items, and machinery on the off-balance sheet account. The reports does not indicate the technical condition of those tractors (good condition or under repairing or broken, but not yet written off from the balance). However those reports provide with the general information and tendencies.

Fig. 2 shows the quantity of tractors in regions of Ukraine. The small number of tractors in the western regions is because this is mountain area and forests. However, agricultural enterprises in these districts exist with the use of agricultural machinery. Obviously, in Ukraine there are no districts with the sufficient quantity of agricultural tractors.

Since the size of agricultural land has not changed, the need of agricultural enterprises in tractors is saturated approximately 40-50%.

In the **Table 1** the marketing information was collected from the State Statistics Service of Ukraine. This represents the number of new tractors sold to the Ukrainian agricultural enterprises in 2011-2016. These tractors were sorted by the power and brands (The State Statistics Service of Ukraine, 2017; 2016; 2015; 2014; 2013; 2012).

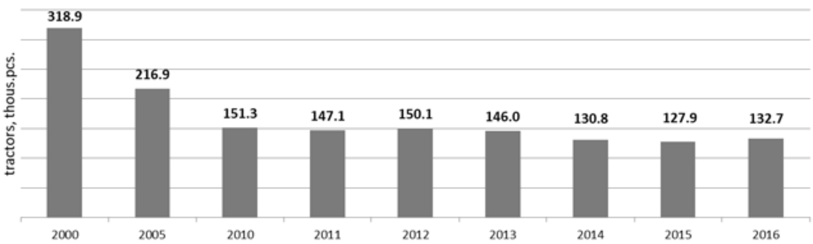

Fig. 1 Agricultural tractors in agricultural enterprises
(Source: The State Statistics Service of Ukraine, 2017; 2016)

Fig. 2 Availability of tractors in agricultural enterprises by regions in 2016
(Source: The State Statistics Service of Ukraine, 2017)

The absolute leader in Ukrainian market is Belarus/MT3 tractors manufactured by the Minsk Tractor Works (Republic of Belarus). In 2016 its share was 35% for 40 kW and less, 87% for 40-60 kW, and 74% for 60-100 kW tractors.

21% of 40 kW tractors were manufactured by Chinese Foton Motor Co.

The share of 60-100 kW tractors was for "New Holland" - 5.6%, "Case" - 3.7% and "John Deere" had 3.4%.

In group 100 kW and higher the one of four (25%) heavy tractors was the "John Deere". Belarus sold 14% from the total, both "Case" and "New Holland" the 13%.

The access to the world market for agricultural machinery was open relatively not long ago for about 25 years. The manufacturers of agricultural machinery consider the Ukrainian market to be one of the most promising. The general tendency of market shares is a transition to the large agricultural tractors.

Ukrainians are traditionally aware and well trained in agricultural machinery. If we take into account economic crises, revolutions, military conflicts and artificial poverty of the rural population, there is a high deferred demand for agricultural machinery in Ukraine. **Fig. 3** shows the dynamics of buying the new tractors in Ukraine over the past 6 years.

In 2014, a military conflict began in the east of the country, in 2014 the inflation per year was 24.9% and in 2015 inflation per year was 43.3%. This affected the purchase of large tractors. But the demand for small tractors remains stable and unchanged. In 2016 there was an increase in sales for 60 kW tractors because of expected deferred demand. Finally the cost of sales in 2016 was estimated from **Table 1** and is shown in **Fig. 4**.

Table 1 Buying of new agricultural tractors by agricultural enterprises in Ukraine

Name of manufacturer	Number of sold new tractors per year						Average price in 2016, USD*
	2011	2012	2013	2014	2015	2016	
All tractors	2,983	3,010	2,788	1,822	2,095	3,777	58,576.90
→ 40 kW and less	70	89	84	59	89	95	11,760.05
"Agromash"	5	6	3	2	1	4	28,219.57
"Belarus"	17	29	16	20	19	34	9,728.42
"HTZ"	10	8	2	7	11	3	7,648.02
"Foton"	3	6	19	7	15	20	10,366.66
"Jinma"	1	2	4	1	1	no data	no data
"Xingtai"	no data	1	2	no data	no data	no data	no data
others	34	37	38	22	42	34	13,037.74
→ 40 to 60 kW	489	458	371	214	222	434	16,554.57
"Agromash"	16	15	5	3	12	5	14,110.35
"Belarus"	244	253	232	108	131	272	15,315.95
"Kii"	5	6	1	1	1	4	14,038.81
"MTZ"	138	124	88	57	52	106	14,978.90
"HTZ"	13	4	5	5	2	2	44,818.75
"UMZ"	5	4	1	no data	1	1	16,745.90
"Foton"	1	no data	no data	1	3	3	12,449.65
others	67	52	39	39	20	41	28,305.94
→ 60 to 100 kW	1,346	1,423	1,216	781	884	1,691	24,836.61
"Agrotron"	35	39	41	27	21	28	32,758.87
"Agrofarm"	5	11	1	4	3	2	14,949.35
"Belarus"	779	772	688	459	517	976	17,832.13
"Kii"	34	24	23	16	21	18	18,509.56
"MTZ"	317	335	255	122	138	285	17,025.24
"UMZ"	10	10	3	1	2	3	21,519.26
"Case"	10	13	9	17	28	62	43,775.06
"Claas"	3	4	2	4	5	3	53,734.30
"Deutz-Fahr"	1	11	2	1	2	6	34,787.72
"Fendt"	1	5	no data	1	3	5	68,393.76
"Foтon"	2	2	3	no data	no data	no data	no data
"John Deere"	29	57	40	21	17	58	69,392.78
"Kubota"	no data	4	no data	no data	1	no data	no data
"Landini"	no data	6	no data	2	8	12	35,050.91
"Massey Ferguson"	1	1	no data	2	2	3	73,669.82
"New Holland"	16	34	38	30	41	94	33,698.07
"Zetor"	3	2	1	6	no data	8	39,794.32
others	100	93	110	68	75	128	53,475.87
→100 kW and more	1,078	1,040	1,117	768	900	1,557	109,790.85
"Belarus"	164	165	153	88	79	220	36,836.93
"Kii"	12	7	16	1	11	16	25,185.28
"LTZ"	no data	5	4	2	1	no data	no data
"HTA"	30	23	18	21	37	55	35,166.59
"HTZ"	149	86	85	154	164	81	42,425.15
"Ag-Chem Terra-Gator"	no data	2	1	no data	1	no data	no data
"Case"	157	111	206	94	123	205	137,938.58
"Challenger"	31	43	29	18	15	9	160,939.66
"Claas"	12	29	25	14	29	69	127,966.64
"Deutz-Fahr"	9	22	27	7	9	8	73,124.43
"Fendt"	43	15	17	24	43	69	183,991.63
"JCB Fasttrac"	4	4	2	2	2	5	127,638.90
"John Deere"	235	280	307	172	185	404	154,503.55

(Continued on next page)

In 2016, Ukrainian agricultural enterprises have bought tractors with the total cost over 221 billion dollars. The main reasons for choosing the certain agricultural machinery is not always price, but the functional and technological characteristics, the quality, and reliability.

Conclusions

The effective agriculture requires the acquisition and adoption of the advanced technologies and machinery. Open competition has made the agricultural enterprises change their approach on pragmatic base. There were above 132 thousand tractors in Ukraine in 2016 and that is approximately 40-50% of the required number.

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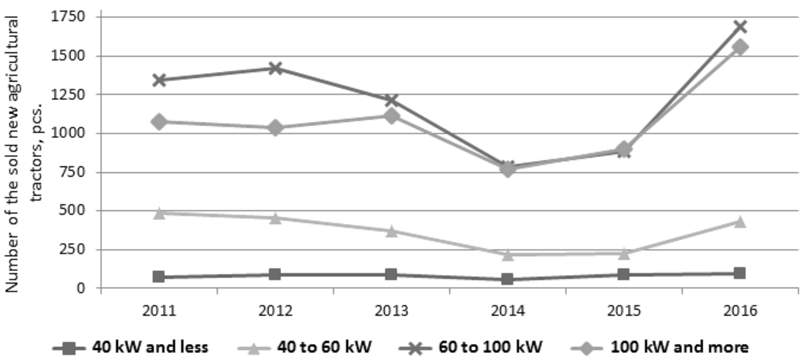

Fig. 3 Sales of new tractors by years

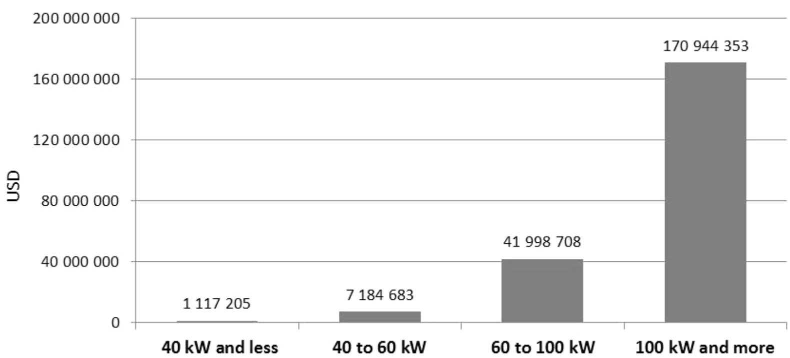

Fig. 4 Total sales of new agricultural tractors in Ukraine in 2016

(Continued from previouos page)

"Kirovets"	2	1	3	1	1	no data	no data
"Lamborgini"	1	6	7	1	2	1	63,542.54
"Landini"	3	1	9	10	4	5	55,545.78
"Massey Ferguson"	5	7	no data	3	9	27	148,232.68
"New Holland"	82	107	108	74	92	220	103,532.62
"Same"	1	1	2	no data	4	2	47,231.55
"Versitayl"	4	3	1	3	no data	4	125,793.12
others	134	122	97	79	89	157	92,736.08

* Average price was transferred into USD by authors on the date 01 Dec. 2016 when the official exchange rate of the National Bank of Ukraine was 25.5585 UAH per 1 USD

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Power Tiller Operated Zero-till Planter for Pea Planting in Rice Fallow of North East India

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Abstract

In rain-fed agriculture of North East India, mono-cropping is practiced in major cultivated land. Experiments conducted to cultivate second crop using residual soil moisture under zero-till condition were successful. A power tiller operated zero-till inclined plate planter was tested for establishment of pea in winter season. The profitability of using the planter for zero-till sowing of pea was compared with traditional method. The planter was operated at three forward speeds of power tiller in three low gears. The machine parameters viz. slip, effective and theoretical field capacities, field efficiency and fuel consumption were measured. The crop parameters of mean plant spacing, plant density, miss and multiple indices and crop yield were also recorded. The results indicated that slip, effective field capacity and fuel consumption increased with increase in forward speed of power tiller. The observed field capacity and field efficiency of zero till planter for planting of pea seeds were 0.047-0.114 ha/h and 63.8-72.7%, respectively and were lower due to clogging of stubbles before the tines and time taken for shifting of power tiller from one terrace to another. Number of multiple seed pick up by the planter was significantly higher (16.28%) at low speed of power tiller as compared to 8.34-11.16% at higher speeds. The planting of pea crop by the power tiller operated inclined plate planter resulted in saving in cost of operation by Rs. 2,797 (US$ 44.4) per hectare.

Keywords: Power tiller; Inclined plate planter; Zero-till; Pea; North-East hill region

Introduction

Agriculture of North East (NE) India is rain-fed. Mono-cropping is practiced in most of the cultivated land in the region due to unavailability of irrigation in rabi season which is one of the major causes of low agricultural production. Cultivation of rabi crops using residual soil moisture after kharif crops under zero-till condition is one way to increase agricultural production. Zero-till cultivation of pea, mustard and toria crops in low-land after harvesting of paddy was successful in terms of productivity and cost in the region. Among these crops, pea was found to give higher productivity of 1,250 kg/ha in zero-till residue management system (Das *et al*., 2012). Besides benefit of productivity, zero-till system conserved water, reduced the requirement of labour, fuel, cost and energy in agriculture (Hobbs and Mehla, 2003) and increased farmers' profit (Gupta *et al*., 2003).

The planting of seeds under zero-till condition is labour intensive and time consuming (up to 25 man-days/ha). It needs opening of furrows in hard soil, planting of seeds in line and covering the seeds. Traditionally it is done by opening furrow using a manual furrow opener and then placing seed and covering them manually. This discourages the farmers to grow a second crop instead of having good potential. For reducing the labour requirement and timely planting of crops under zero-till condition, there is a need of an efficient machine which can perform all three operations at a time with reduced cost and energy requirement.

Tractor operated zero-till seed drills were not suitable in NE region due to heavy weight of tractor and very small size of plots. The most suitable and widely accepted source of farm power for most of agricultural operations in NE India was two wheel hand tractor called power tiller. In Assam alone, more than 30,000 power tillers are in use (Mandal *et al*., 2014). Therefore, a power tiller operated zero-till seed drill, fitted with fluted roller seed metering device, is suitable for sowing of rice, wheat and other similar seeds. But the fluted roller metering was not suitable for planting pea due to higher damage during metering. So, the metering unit was changed to an inclined plate metering for planting of pea seeds. Inclined plate metering device was found efficient in reducing seed rate and cost of production (Srivastava *et al*., 2003). For this purpose, the planter was evaluated for planting of pea in rice fallow under zero-till condition at different forward speeds to find out optimum performance. It will help farmers to enhance cropping intensity and productivity in the region.

Fig. 1 Testing of zero-till inclined plate planter in rice fallow

Table 1 Properties of pea seeds selected for the study

Properties	Range	Mean (±SD)
Length, mm	5.2-7.9	6.7 (±0.4)
Width, mm	5.2-6.8	6.2 (±0.3)
Thickness, mm	5.1-6.4	5.9 (±0.3)
Frontal area, mm^2	20.4-36.5	30.4 (±2.8)
Sphericity	0.75-0.95	0.85 (±0.1)

Materials and Methods

Physical Properties of Pea Seeds

The most popularly grown variety of pea in Meghalaya is Prakash. From a seed lot of this variety, 50 seeds were randomly selected and physical properties were determined and results are given in **Table 1**. Dimension were determined using a Vernier caliper with an accuracy of 0.1 mm. Frontal area of seeds was determined using the method described by Mandal *et al.* (2012). The average length, width and thickness of pea seeds were 6.7, 6.2 and 5.9 mm, respectively. Its shape was spherical as sphericity was more than 0.80 (Bal and Mishra, 1988).

Field Conditions

The experiments were conducted in a low land field (950 m at sea level, 25°30′ N latitude and 91°51′ E longitude) surrounded by hillocks. The plots were under rice cultivation for about two decades. Every year two operations of rotavator (up to 150 mm depth) by power tiller were conducted before transplanting of rice. Average bulk density, moisture content and penetration resistance of the plots are reported in **Table 2**. In the RNAM (Regional Network for Agricultural Machinery) guidelines, plot size of 20 m × 10 m was recommended for testing of agricultural machines (RNAM, 1995). But in hilly terrain it was difficult to get a 10 m wide plot. Therefore, rice fallow plots of size 20 × 8 m were selected for testing of the implement. There was 3 t/ha of rice stubbles of an average height of 255 mm in the field (**Fig. 1**). The tines were operated in the space between stubbles to avoid excessive clogging of tines in the field.

Design of The Zero-Till Planter

The planter (**Fig. 1**) consisted of inclined plate metering mechanism, three zero-till tynes, seed hopper, chain drives, ground wheel and main frame with hitch bar. The metering plate was 120 mm in diameter and 6 mm in thickness and had 20 oblong cells surrounding its periphery. It had a picking angle of 53°. Each cell had an inclination angle of 30° to hold the seeds from falling. Inclination angle of the plate was kept 60° with the vertical (Sahoo and Srivastava, 2000; Anantachar *et al*., 2012). Each plate was concentric with a bevel gear rotated by another bevel gear with speed ratio of 1.6:1. All the driving bevel gears were mounted on a common shaft which was driven by a set of chain and sprockets for changing seed to seed spacing. The main driving sprocket was attached with the driving ground wheel of 400 mm diameter. Each seed hopper had a length of 210 mm and top width of 150 mm with side slope of 60° and 0°. Tines of the planter were fitted with inverted “T” type furrow openers (Chaudhuri, 2001).

Table 2 Physical properties of the soil of experimental plots

Properties	Depth, mm		
	0-50	50-100	100-150
Bulk density, Mg/m^3	1.15	1.28	1.32
Soil moisture content, % db	77.42	80.22	82.14
Penetration resistance, kPa	175	214	289

Experimental Procedure

The planter was operated in the field at three forward speeds of Low-1 (L_1 = 1.48 km/h), Low-2 (L_2 = 2.18 km/h) and Low-3 (L_3 = 3.43 km/h). The observations were taken for wheel slippage, field capacity, field efficiency and fuel consumption following methods described by Mehta *et al.* (1995). The experimental trials were conducted in winter season (December to March) of 2013 after the harvesting of paddy to utilize the residual moisture. Wheel slippage was measured by counting number of revolutions of power tiller wheel within a span of 20 m on the field and dividing this by number of rotation on concrete floor. The total time taken to complete the selected plot was noted to determine actual field capacity. It included the time for turning, filling seeds, removing clogged stubbles from tines and transporting the power tiller from one terrace to another. Field efficiency was calculated by dividing actual field capacity by theoretical field capacity. Each set of experimental trials were replicated three times. Seed to seed spacing within a row and number of plants per unit area or plant density are most important parameters for a precision planter (Heege, 1993). Therefore, crop establishment parameters such as average plant spacing and plant density at different speeds were measured after 30 days of planting. The data were analyzed using SPSS (Ver 16.0, IBM, USA) to find out the significant differences among the means. Duncan's multiple tests were carried out for least square differences.

Results and Discussion

Performance of The Planter Under Field Condition

The performance of the planter was determined at three forward speeds of the power tiller and results are presented in **Fig. 2 a-d**. The power tiller was operated multiple times on concrete floor to find out the actual speed of travel. The forward speeds of power tiller were 1.48, 2.18 and 3.43 km/h in gears L_1, L_2 and L_3, respectively. The wheel slip of power tiller was also higher due to high moisture content of the experimental plots. It was observed that wheel slip of power tiller in L_3 gear was significantly ($P<0.05$) higher as compared to wheel slips in L_1 and L_2 gears (**Fig. 2a**). It was observed that higher wheel speed increased drawbar pull significantly which increased slip and hence the reduction in drawbar power (Zoz, 1970; Narang and Varshney, 2006). However, wheel slips at speeds of 1.48 and 2.18 km/h were lower than that observed for two-wheel tractor operated zero-till seed-cum-fertilizer drill evaluated with maize and wheat by Haque *et al.* (2004).

The effective field capacity (EFC) of power tiller operated planter increased significantly with increase in forward speed of operation (**Fig. 2b**). This was due to low time requirement in turning of the machine at higher speed. Similar results were observed by other researchers (Pradhan *et al.*, 1997; Haque *et al.*, 2004; Matin *et al.*, 2008). Matin *et al.* (2008) reported field capacity of 0.19 ha/h for power tiller operated maize planter in well prepared field condition. Pradhan *et al.* (1997) found EFC of 0.16 ha/h with power tiller operated groundnut planter-cum-fertilizer drill and 0.18 ha/h for zero-till seed-cum-fertilizer drill (Haque *et al.* 2004). In this experiment, the observed EFC was 0.047, 0.071 and 0.114 ha/h at forward speeds of 1.48, 2.18 and 3.43 km/h, respectively. The reasons behind low EFC were that all the terrain was hilly which took a considerable time to shift the whole machine from one terrace to another. Due to high moisture content of experimental plots, rice was harvested at ear head level leaving higher amount of stubbles which clogged the inter-row space between tines causing higher time requirement to unclog the tines. Thirdly, the moisture level in the field was high which caused higher slippage reducing the overall field capacity. Field efficiency was recorded significantly higher at

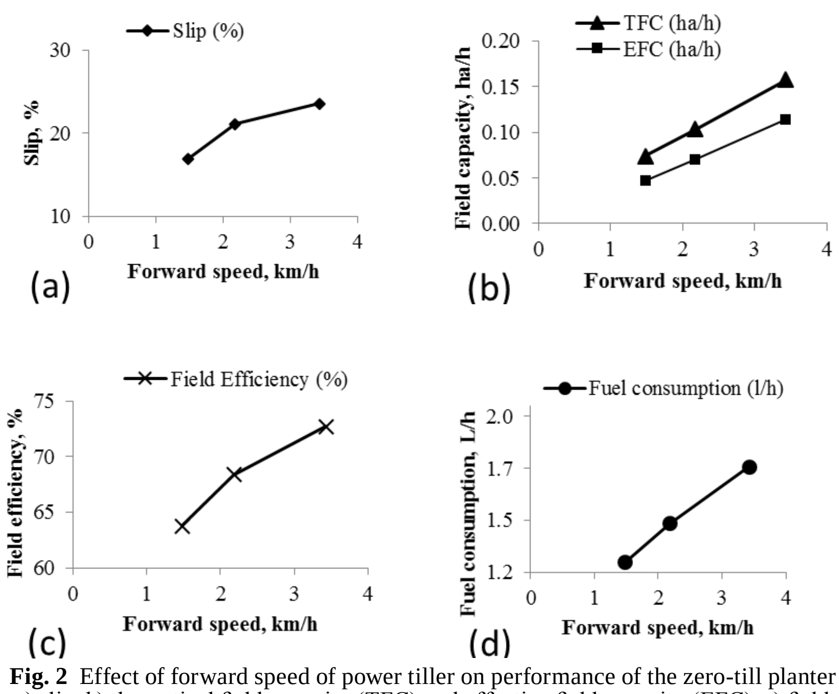

Fig. 2 Effect of forward speed of power tiller on performance of the zero-till planter a) slip, b) theoretical field capacity (TFC) and effective field capacity (EFC), c) field efficiency and d) fuel consumption

forward speed of 3.43 km/h as compared to 1.48 and 2.18 km/h speed. However, the observed field efficiency at higher speeds was lower than previous studies (Pradhan *et al*., 1997; Haque *et al*., 2004; Matin *et al*., 2008) (**Fig. 2c**).

The fuel consumption was directly affected by speed and slip of power tiller. As a consequence, higher fuel consumption was recorded at higher speed (**Fig. 2d**). The average fuel consumption was recorded as 1.25, 1.44 and 1.71 L/h at forward speeds of 1.48, 2.18 and 3.43 km/h, respectively. These values were also on higher side as compared to zero-till seed-cum-fertilizer drill operated with maize and wheat crop where fuel consumption was 1.25 and 1.40 L/h, respectively at forward speed of 2.2 km/h (Haque *et al*., 2004). These results suggest that low speed operation is economical as far as fuel consumption is concerned.

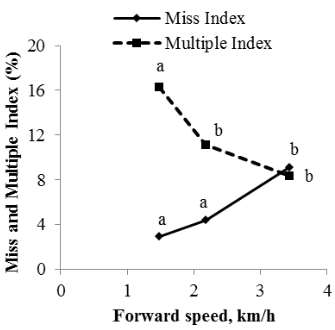

Fig. 3 Miss and multiple indices of pea seeds metered by the zero-till planter at different forward speeds of operation

Crop Establishment and Yield

Miss and multiple indices of pea seeds are presented in **Fig. 3**. Number of multiple seed pick up (16.28% in L_1 gear) was significantly higher at low speed as compared to higher speed (11.16% in L_3 and 8.34% in L_2 gears). Multiple pick up of seeds can be minimised by selection of uniform size seeds. The miss index in L_3 gear of power tiller was higher which was due to high speed of seed metering plate (Anantachar *et al*., 2010). The average seed spacing in L_1, L_2 and L_3 gears of power tiller was recorded as 97, 103 and 115 mm, respectively, against the planter set spacing of 100 mm (**Fig. 4a**). Although average spacing was close to set spacing, higher variation was recorded. Standard deviation of seed spacing was noted higher in L_3 (±55 mm) and followed by L_1 (±41 mm) and L_2 (±38 mm). It indicated that low speed was good for placing the seeds in slits with higher accuracy (Haque *et al*., 2004).

Although there were significant differences in miss, multiple and average spacing, not much difference was found in plant density (**Fig. 4b**). The higher plant density was observed in L_1 gear of power tiller due to higher multiple as compared to that during L_2 and L_3 gears of power tiller. Lesser yield of pea of 1,102 kg/ha was recorded at 3.43 km/h speed (L_3 gear) of power tiller as compared to L_2 (1,196 kg/ha) and L_1 (1,215 kg/ha) gears (**Fig. 4c**). It indicated that dry yield of pea was significantly affected by speed of operation of power tiller. The lesser yield at high speed may be due to higher miss index and lesser plant density.

Table 3 Economics of the planter operation at different speeds

Parameters	Manual	Zero-till planter		
		L_1	L_2	L_3
Field capacity, ha/h	-	0.047	0.071	0.114
Operational time, h/ha	192	21	14	9
Fixed cost of planter, Rs.*/ha	-	252	*168*	*108*
Power tiller rent, Rs./ha	-	1,575	1,050	675
Fuel consumption, L/h	-	1.25	1.44	1.71
Total fuel consumption, l/ha		26.25	20.6	15.4
Fuel cost @Rs. 57/L, Rs./ha	-	1,496	1,174	878
Operator's cost, Rs./ha	-	798	532	342
Total operating cost of the planter, Rs./ha	-	*3,869*	*2,756*	*1,895*
Total fixed and operating cost, Rs./ha	4,800	4,121	2,924	2,003

*1 US$ = Rs. 63

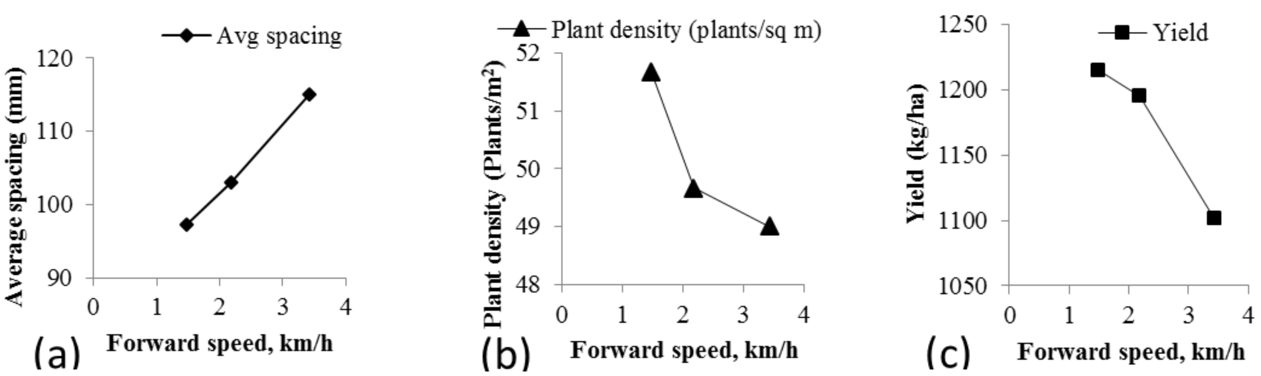

Fig. 4 Effect of different forward speeds of power tiller on pea crop parameters planted by zero-till planter (a) average spacing, (b) plant density and (c) crop yield

Economics of the Planter

As there was no suitable other machinery for zero-till planting of pea seeds, the cost of planting of seeds with the power tiller operated planter was compared with the cost of manual planting (**Table 3**). The initial cost of the planter was estimated to be Rs. 12,000 (US$ 190.4). Considering straight line depreciation and a total life span of 1,000 h, depreciation cost was found to be Rs. 12 per hour (US$ 0.19) (Gaikwad and Sirohi, 2008). The custom hiring rates of power tiller and daily wages of operator in the region was Rs. 600 (US$ 2.38) and Rs. 300 (US$ 1.19), respectively. Thus, considering 8 h as working time per day, wage rate of power tiller and operator was Rs. 75/h and Rs. 38/h, respectively.

If done manually, zero-till planting involves three operations viz. opening of furrow, placing of seeds and covering. The most tiring operation among these is the opening of furrow which is done by a manual furrow opener. For row-to-row spacing of 200 mm, total man power requirement for zero-till planting will be 24 man-days per hectare. With prevailing labour wage rate of Rs. 200 (US$ 3.17) per day in the region, cost of the total manpower requirement for planting one hectare will be Rs. 4,800 (US$ 76). Sometimes, at peak agricultural season this may go up to Rs. 300-400 per day. A comparative cost calculation has been summarized in **Table 3**. It shows that the total cost of planting one hectare at 3.43 km/h speed (L_3 gear) of power tiller will be half of the cost in L_1 gear and equals to 41.73% of the cost of manual planting. Thus, a total saving of Rs. 2,797 (US$ 44.4) per hectare could be achieved by planting with the power tiller operated inclined plate planter. It indicated that farmer would recover the initial planter cost of Rs.12,000 within 38.6 hours of operation of the planter.

Conclusions

The study indicated that power tiller operated inclined plate planter could be used to solve the problem of zero-till planting in rice fallow. With proper moisture in the field, the planter can be operated in all low gears of the power tiller. Wheel slip in third low gear of power tiller was 23.6% which was significantly higher than other two low gears. However, effective field capacity and field efficiency was 0.114 ha/h and 72.7%, respectively in third low gear which were higher than first and second low gears. There was constraint in smooth operation in the field due to stubbles which reduced the field efficiency. This can be overcome by operating the machine at higher speed. At third low gear of power tiller, machine parameters were at higher side except fuel consumption but crop parameters were on lower side. Fuel consumption was 1.71 L/h which was significantly higher than other two speeds. But yield was 8.5% and 10.28% lesser than second and first low gears. However, cost of operation was significantly lower in third low gear. A total saving of Rs. 2,797 (US$ 44.4) per hectare could be achieved by planting with the power tiller operated inclined plate planter at third low gear. Thus, farmer can recover the initial planter cost within 38.6 hours of operation. Moreover, this implement can help in cultivating two consecutive crops in the region fetching some more foods with little investment.

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EVENT CALENDAR

◆ **2018 Agricultural Equipment Technology Conference**
February 12-14, Kentucky, USA
http://www.asabe.org/meetings-events/2018/02/agricultural-equipment-technology-conference.aspx

◆ **World Ag Expo**
February 13-15, California, USA
https://www.worldagexpo.com/

◆ **National Farm Machinery Show**
February 14-17, Kentucky, USA
http://www.farmmachineryshow.org/

◆ **FIMA—The 40th International Fair of Agricultural Machinery**
February 20-24, Saragossa, SPAIN
https://www.feriazaragoza.es/fima-agricola-2018

◆ **Hortex Vietnam 2018—The First International Exhibition and Conference for Horticulture and Floriculture Production and Processing Technology in Viet Nam**
March 14-16, Ho Chi Minh City, VIET NAM
https://www.hortex-vietnam.com/

◆ **ALLSENSORS 2018—The Third International Conference on Advances in Sensors, Actuators, Metering and Sensing—**
March 25-29, Rome, ITALY
http://www.iaria.org/conferences2018/ALLSENSORS18.html

◆ **Autonomous Trucks—2nd International VDI Conference—**
April 10-11, Dusseldorf, GERMANY
https://www.vdi-wissensforum.de/en/event/autonomous-trucks/

◆ **XIX. World Congress of CIGR**
April 22-25, Kyneria, TURKEY
http://www.cigr2018.org/

◆ **NAMPO Harvest Day**
May 15-18, Bothaville, SOUTH AFRICA
http://www.grainsa.co.za/pages/nampo/exhibitors

◆ **Caspian Agro 2018—12th Azerbaijan International Agriculture Exhibition—**
May 16-18, Baku, AZERBAIJAN
http://caspianagro.az/en-main/

◆ **SIMA ASEAN**
June 6-8, Bangkok, THAILAND
http://www.sima-asean.com/en/

◆ **GreenTech**
June 12-14, Amsterdam, NETHERLANDS
http://www.greentech.nl/amsterdam/

◆ **Asia Agri-tech Expo & Forum**
July 26-28, Taipei, TAIWAN
http://www.agritechtaiwan.com/en-us/

◆ **EURAGENG 2018 Conference**
July 8-12, Wageningen, THE NETHERLANDS
http://ageng2018.com/

◆ **2018 ASABE Annual International Meeting**
July 29-August 1, Detroit, USA
https://www.asabe.org/meetings-events/2018/07/2018-asabe-annual-international-meeting.aspx

◆ **Agritechnica Asia 2018**
August 22-24, Bangkok, THAILANS
http://www.agritechnica-asia.com/

◆ **Global Wter Security for Agriculture and Natural Resources**
October 3-6, Hyderabad, INDIA
http://asabewater.org/

◆ **Agrosalon**
October 9-12, Moscow, RUSSIA
http://www.agrosalon.com/Visitor/VisitorsInfo/

◆ **KIEMSTA 2018**
October 31-November 3, Cheonan, KOREA
http://kamico.or.kr:8001/KIEMSTA/e-main.html

◆ **EIMA 2018**
November 7-11, Bologna, ITALY
https://www.eima.it/en/index.php

◆ **EuroTier**
November 13-16, Hanover, GERMANY
https://www.eurotier.com/

◆ **Nebraska Power Farming Show**
December 4-6, Nebraska, USA
https://nebraskapowershow.com/

2019

◆ **SIMA**
February 24-28, Paris, FRANCE
https://en.simaonline.com/

◆ **Agritechnica**
November 10-16, Hanover, GERMANY
https://www.agritechnica.com/en/

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International Commission of Agricultural and Biosystems Engineering (CIGR)

12TH CIGR SECTION VI (Postharvest Technology & Bioprocess Engineering) INTERNATIONAL SYMPOSIUM

THEME: Innovations and Technologies for Sustainable Agricultural Production and Food Sufficiency

Monday 22-Thursday 25 October, 2018/ Institute for Tropical Agriculture (IITA), Ibadan, NIGERIA

Sub-themes

1. Postharvest Technologies and Processes
2. Engineering Technologies for Fruit, Vegetables, and Other Specialty Crops
3. Agro processing, value addition and poverty alleviation
4. Information and Communication Technologies for postharvest processing
5. Renewable Energy Resources in Agricultural and Food Production
6. Energy Utilization and Application in Agricultural Facilities, Processes and Operations
7. Reduction of postharvest losses and agricultural financing
8. Dairy Value Chain and Entrepreneurship
9. Handling, Storage, Transport, and Processing of crops
10. Gender roles Postharvest and Agro processing technologies
11. Innovative Resource Systems and Energy Strategies in Controlled Environments

Call for Papers

Conference organising committee now wishes to invite for papers on any of the sub-themes. Authors are invited to submit abstracts of their papers online.

More information on paper submission visit www.cigrvinigeria2018.org

Please follow the guidelines for full paper submission by visiting www.cigrjournal.org

Submit abstract after registration online at www.cigrvinigeria2018.org

Conference Structure

Keynote speeches, platform presentation, plenary discussion, poster presentations, technical tours and exhibitions.

Technical and Social Tours

There is a technical tour on *Thursday, October 25, 2018* to an agro based industry that relied on IITA technology to feed Africa, the company is based in Ilero, Oke-Ogun area of Oyo state, Nigeria. The trip is design to unwind you and bring psychological relief but full of education and fun. It will be seen as complete review of crop processing and storage curriculum. Niji Group https://www.nijigroup.com/ operate in different fields. It started as fabrication outfit but diversified into agro-allied equipment and machinery manufacturing, sales and services, now own a very large farm single handedly producing his own raw material for the manufacturing of Nijifoods. The equipment in use are fabricated mainly by him for the food processing while innovating with modern tools to facilitate quality processing. It is the first company to have modern cassava and yam peeler. The crop processing outfit known as NijiFoods at Ilero in Oke-Ogun Area of Oyo state is an excellent place to visit by all. Visitors are welcome to the integrated farm/factory settlement where processing of Cassava and Yam into food items such as Gari (sour), Gari (Vitamin A), Odourless Fufu, Odourless Vita Fufu, Yam Flour, Pounded Yam flour, High Quality Cassava Flour takes place. NijiLucas also currently assembles tractor. It is good place to visit (110 km away from Ibadan). Post conference tours may be arranged at individuals cost on Friday, October 26, 2018 to IITA (Cassava Value Chain Project, Aflasafe, Farm, Greenhouses, Dam and Workshop) and University of Ibadan (Dept. of Agricultural Engineering, Zoo, and Botanical Garden)

Dates and Deadlines

Abstracts Due: April 2, 2018
Notice of Acceptance: April 27, 2018
Full Paper Submission: July 27, 2018

Online Registration Opens: April 30, 2018
Early Bird Registration Ends: August 30, 2018
Online Registration Closes: September 7, 2018
Deadline for Hotel Reservations: September 3, 2018
Conference dates: October 22-25, 2018

Registration

Online registration will open on April 30th 2018. Only online and mail-in payment will be accepted. Registration payment method is by bank transfer.

Registration Fee	Early Registration	Regular Registration	Late Registration
	Before 30 July 2018	Before 30 Sept 2018	After 30 Sept 2018
Normal	$400	$450	$500
Developing countries*	$350	$400	$450
Extras			
Technical tour	$30	$30	$30
Social dinner	$20	$20	$20
Accompanying spouse	$150	$150	$200

Payments

Payments are securely processed through our bank transfer only (For International Participants)

Bank account details

Account name	International Institute for Tropical Agriculture (CC.8564 - CIGR Workshop)
Account number	10088691
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Benefits of Attending the Cigr Section VI International Symposium

1. Current trends in postharvest technology and processing engineering
2. Networking with researchers and academics from across the world
3. Publication of conference papers in proceedings.
4. Publication of high quality papers with international and impact journals (CIGR, AMA, etc). Selected papers will be published in a special edition of CIGR Journal
5. Opportunity of meeting experts in the field
6. Possible initiation of linkages with International institutions
7. Opportunity of belonging to International Organisations (CIGR, PASAE, ASABE etc)
8. Interaction with industrialists and practitioners
9. Conference in a secure and safe environment
10. Excellent and standard facilities for all sessions of the conference
11. Excellent transportation and movement during the conference
12. Exposure to IITA research outputs and field excursions
13. Value for money (Full conference registration include network welcome reception, all lunches and mid-session coffee breaks, USB pen with full texts, participation in the official conference program and participant's package.

Enquiries

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The Next Issue Is Our Third Special Issue: Agricultural Mechanization and Industry in Africa

We've annually published a special issue since 2016. The previous ones are on the agricultural mechanization in Asia. This time we focus on Africa, especially Sub-Saharan region. The followings are the countries which will be reported in the issue:

Nigeria, Egypt, Morocco, Sudan, Kenya, Tanzania, Ghana, Côte d'Ivoire, Uganda and Madagascar.

In addition to that, it'll contain each article on Sub-Saharan region and the African continent. And Chinese and Indian strategies for African market will be reported.

Enjoy your reading and see you next issue!

■■

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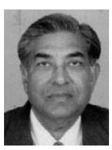
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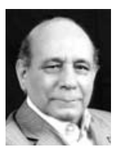
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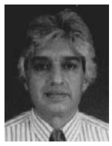
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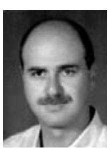
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Bala Krishna Shrestha	Nepal	1972	1991	Suppiah Kathirkamathamby	Sri Lanka	1981	1991
Chul Choo Lee	Korea	1972	2014	Armed Hossain Mirdha	Mexico	1982	1991
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Merle L. Esmay	U. S. A.	1972	1990	Kshirode Chandra Roy	Bangladesh	1982	1985
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Bilash Kanti Bala	Bangladesh	1976	1982	A. P. Kaloyanov	Bulgaria	1985	2013
George B. Hanna	Egypt	1976	1988	Soedjatmiko	Indonesia	1986	2014
Jun Sakai	Japan	1976	2015	Aalbert Anne Wanders	Netherlands	1988	2007
Siswadhi Soepardjo	Indonesia	1976	1985	Ali Mahmoud El Hossary	Egypt	1988	2010
Tieng-Song Peng Taiwan	Taiwan	1976	2015	Chanchai Rojanasaroj	Thailand	1988	2011
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Amala Prasad Sharma	Fiji	1978	1981	T. P. Ojha	India	1988	2015
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Bherulal T. Devrajani	Pakistan	1978	2004	Henrik Have	Denmark	1990	2009
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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Vol.48, No.2, Spring 2017

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Vol.48, No.3, Summer 2017

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Vol.48, No.4, Autumn 2017

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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 –

a. are written in the English language;
b. are relevant: to the promotion of agricultural mechanization, particularly for the developing countries;
c. have not been previously published elsewhere, or, if previously published are supported by a copyright permission;
d. deal with practical and adoptable innovations by, small farmers with a minimum of complicated formulas, theories and schematic diagrams;
e. have a 50 to 100-word abstract, preferably preceding the main body of the article;
f. are printed, double-spaced, under 3,000 words (approximately equivalent to 6 pages of AMA-size paper) ; and those that
g. art: supported by authentic sources, reference or bibliography.
h. written in MS DOS format.

Rejected/Accepted Articles

a. As a rule, articles that are not chosen for AMA publication are not returned. At the earliest time possible, the writer(s) is advised whether the article is rejected or accepted.
b. When an article is accepted but requires revision/modification, the details will be indicated in the return reply from the AMA Chief Editor in which case such revision/modification must be completed and returned to AMA within three months from the date of receipt from the Editorial Staff.
c. The AMA does not pay for articles published.
d. Complimentary copies: Following the publishing, three successive issue are sent to the author(s).

Procedure

a. Articles for publication (original and one-copy) must be sent to AMA through the Co-operating Editor in the country where the article originates. (Please refer to the names and addresses of Co-operating Editors in any issue of the AMA). However, in the absence of any Co-operating Editor, the article needs to be sent to Co-operating Editor in the writer's neighboring country. Please note that it is AMA Chief Editor that decide whether publish each submitted paper on AMA or not. Even if Co-operating Editor found your manuscript suitable for publication on AMA, it can not the case with AMA Chief Editor.
b. Contributors of articles for the AMA for the first time are required to attach a passport size ID photograph (black and white print preferred) to the article. The same applies to those who have contributed articles three years earlier. In either case, ID photographs taken within the last 6 months are preferred.
c. The article must bear the writer(s) name, title/designation, office/organization, nationality and complete mailing address.

Format/Style Guidance

a. Article must be sent by E-mail with Word File and PDF File attached.
b. The data for graphs and photographs must be saved into piecemeal data and enclosed (attached) with the article.
c. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features:
   (i) brief and appropriate title;
   (ii) the writer(s) name, designation/title, office/organization; and mailing address;
   (iii) an abstract following ii) above;
   (iv) body proper (text/discussion);
   (v) conclusion/recommendation; and a
   (vi) bibliography
d. Tables, graphs and diagrams must be numbered. Table numbers must precede table titles, e.g., "Table 1 Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Fig. 1 View of the Farm Buildings".
e. **The data for the graph must also be included. (e.g. EXCEL for Windows)**
f. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
g. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
h. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
j. Convert national currencies **in US dollars** and use the later consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
l. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..."instead of 45 workers..., or, 5 tractors.

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