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This is the 161th issue since its maiden isue in the Spring of 1971

EDITORIAL

CIGR (International Commission of Agricultural and Biosystems Engineering: Commission lnternationale du Genie Rural) was held from September 16th to 18th in Beijing, China. More than 2,000 people from various countries joined the meeting. The meeting was well organized and very successful. Many Chinese delivered research presentations, and it revealed that the large number of researchers study agricultural engineering in China.

China, having the highest population of 1.3 billion, has to improve its food self-sufficiency ratio and makes a substantial investment in agriculture. The government subsidizes particularly to the aging villages to promote agricultural mechanization. China became one of the biggest machinery producing countries as 2.5 million four-wheel-tractors were produced in 2013 and more than 10,000 small and large manufactures exist. However, some villages still use human labour instead of agricultural machines. Therefore, the agricultural machinery market is expected to grow. The specific labour is important to increase the productivity with the limited land space and with the climate change, and it is still necessary to promote farm mechanization to stabilize the food production.

At present, the world population is over 7.2 billion and is expected to grow to 8 billion and 9 billion. It is our duty to increase food production with the appropriate use of limited resources of farmland, water and so on. The technology to effectively use the resources, particularly engineering technology is significant and we must promote the mechanization in the world. It is easy to use machines in large and flat farmland as seen in many countries, but many farmlands are actually on the steep hillside and small. It is crucial to promote the mechanization in these farmlands. With the growing population in the cities, reduced number of youth on farms, and lack of agricultural machinery for small-scaling farming, many farmlands will be abandoned. The new technologies such as intelligent small agricultural robots are essential.

It has passed 43 years after the first publication of AMA which has been to promote agricultural mechanization in the developing countries and to motivate communication. I would continue publishing AMA for the advancement of farm mechanization and would like to seek cooperation from many readers and professionals.

Yoshisuke Kishida
Chief Editor

October, 2014

CONTENTS

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Paddy Rice Production Mechanization in China —A Review

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Abstract

Paddy rice plays a significant role in food security of China, contributing to 33.25 % of the planting area and 39.44 % of the production of sown grain crops. However the mechanization level of paddy rice production is still low. The paper analyzed the development status of paddy rice production mechanization in different regions, and the influencing factors. Results showed the mechanization level is still low in China, and it has great spatial variation, with the northern paddy region tops the list of all regions, while double cropping paddy region hold the lowest level. Concerning on paddy rice field planting technologies, mechanical transplanting is the most dominant one in use and in the future, contributing to over 80 % of the mechanical planting area. The bottlenecks for paddy rice mechanization development include complicated topography, small farm size, lack of agricultural machinery, farmers' low education level and poor economic condition.

Introduction

Paddy rice is one of the staple foods in China, being planted in 30 provinces and areas. In 2010, the planting area and production of paddy rice in China was 29,873 kha and 195.7 million tons, with the average yield of 6.55 tons per hectare (NBSC, 2011). To feed the population of 1.45 billion in 2020 estimated by National Population Development Strategy Research Group (2007), about 208 million tons of rice will be required, while the production of which is still a great challenge, due to limited area of cultivation, lots of abandoned fields, and low level of mechanical field operation. The present production is not sufficient to mitigate the requirement of growing population. Researches proved the development of paddy rice production mechanization can release the labor requirement and reduce production cost, also plays a dominant role in paddy rice area augmentation and sustainability (Sun, 2004; Liu, 2009).

In 2010, mechanical level of paddy field tillage, planting, and harvesting reached to 86.64 %, 20.86 %, and 64.49 % in China, according to the census of the Ministry of Agriculture, P.R.C (2010). Because of the high physical strain, young farmers in many regions are unwilling to stay on agriculture to continue paddy rice planting. Also due to the increasing cost of labor and other input like seeds, fertilizers, insecticides, farmers found it difficult to achieve economic profit in paddy rice production.

The adoption of improved field operation technologies and implements is necessary for better germination and proper plant stand and less loss during harvesting. It is need of the hour to change agricultural strategy to increase rice yields through machinery application to meet food requirement of increasing population. However, it is confronted by technological, economical, physical and social constraints, which must be overcome in order to maintain paddy rice production.

Objectives

The specific objectives of this paper were:

1. To analyze the present mechanization level of paddy rice production both national and regional;
2. To discuss the cultivation practices and machineries used in each field operation and the technology development trends;
3. To analyze the major constraints of mechanization development.

Present Level of Paddy Mechanization

Paddy Regions

Different regions have different climate conditions ranging from tropical climate to extremely cold weather and various soil textures ranging from sands to heavy clays in China. Annual precipitation also has temporal and spatial variation. Based on natural conditions and farming systems, as well as provincial geographical locations, paddy rice production in China is divided into four regions includes Double-cropping paddy rice region (Region A), Middle and lower reaches of Yangtze River paddy rice region (Region B), Southwestern paddy rice region (Region C), and Northern paddy rice region (Region D) (**Fig. 1**).

Region A includes five provinces (Hunan, Jiangxi, Fujian, Guangdong, and Hainan) and one municipality (Guangxi Zhuang Autonomous Region). It is the largest paddy area, with the planting area of 12,575 kha and the production of 71.92 million tons, accounting for approximately 40 % of the national paddy rice planting area and production. The average yield is 5.72 tons per ha, which is far behind the average yield of national and other regions. Region B includes four provinces (Anhui, Jiangsu, Zhejiang, Hubei) and one municipality (Shang hai). It has a planting area of 7,549 kha and the production of 54.87 million tons. It is the second largest paddy rice planting area, contributing to over 25 % of the planting area and production of the country. The average yield is 7.27 tons per ha, which is the highest among regions.

Region C includes three provinces (Sichuan, Yunnan, and Guizhou) and one municipality (Chongqing). It has a planting area of 4,405 kha and a production of 30.93 million tons, and the average yield is 7.02 tons per ha.

Region D includes all the other 14 northern provinces and municipalities. It has a planting area of 5,342 kha and the production of 38.02 million tons and the average yield is 7.12 tons per ha.

Present Mechanization Level

The farmers face difficulty in timely completion of field operations for paddy rice production due to lack of young labor force and lack of advanced machinery and related implements (Chen, 2008), like the implements for tillage operation, domestic manufactured transplanter, low price semi-feed combine, as well as dryer. To explore the possibility of further improve paddy rice production mechanization, current development status of paddy field operations, technologies and machineries has been reviewed.

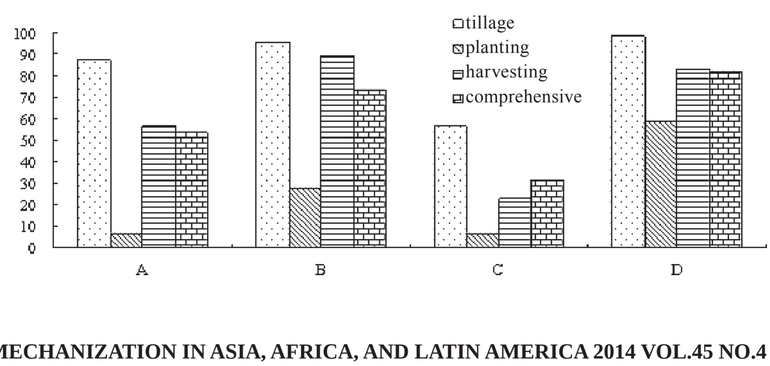
Generally speaking, the mechanical level of paddy rice field operation is still low and differed from region to region. In 2010, the national mechanizetion level of tillage, planting and harvesting were 86.64 %, 20.86 % and 64.49 % (MOA, 2010). Following with The Evaluation for the Level of Agricultural Mechanization -Part 1：Crop Cultivation (standard number：NY/T 1408.1-2007), the national comprehensive level of paddy rice production mechanization was 60.26 %. The level of the regions were listed as Region A (53.48 %), Region B (73.26 %), Region C (31.31 %), Region D (81.72 %). Region D had the highest mechanization level of tillage and planting, which were 98.21 % and 58.31 %. Region B had the highest mechanization level of harvesting, which was 89.05 %. Region C had the lowest mechanical level of tillage and harvesting, which were 56.68 %, and 22.65 %. Region D has the lowest mechanical level of planting among all the regions, which was only 5.98 %, as shown in **Fig. 2**.

Field Operation Technologies and Machinery Field Preparation

Field preparation played a significant role in crop establishment. Paddy field need to be even in order to implement mechanical transplanting, since the uneven field will result with poor quality of plantation (Cai *et al*., 2006). It is also the most power intensive operation. A minimum of three to six passes are needed for paddy land preparation, including ploughing, fertilizer and chemical application, and clod breaking. Most farmers use mechanized tillage operation, tractors and tractor drawn implements such as disc plough, disc harrow, mouldboard or chisel plough, ripper and drill machines. In south China, float tillage machine is also adopted for deep mud field. Some of the fields are prepared with simple hand tools, like bullocks for

Fig. 1 Paddy Regions in China

Fig. 2 Paddy Rice Production Mechanization in Four Paddy Regions China



ploughing, and spade for ridging and furrow formation.

Seedling raising

Paddy rice is propagated by three different kinds of technologies, which are blanket type seedling raising, pot seedling raising and open field seedling raising. All the methods can be done both manually and mechanically. Blanket type seedling raising is the most dominant technology in use nowadays with its high adaptability and afford able cost. It mainly uses hard or soft plastic seedling bowls or two layers of plastic films.

Planting

Seedling raising and plant stand establishment are the most crucial requirements in paddy rice production. Three methods of paddy rice planting are used in China include direct seeding, transplanting and throwing transplanting. Direct seeding did not need to raise seedling. It is labor saving and easy to handle, while the adoption of the technology has limitations. It is more suitable to be used in cold regions with long planting season, and lack of labor force. Transplanting is done manually or mechanically with raised seedlings. This method can increase the yield greatly due to better plant germination and crop stand, it also has high feasibility. Throwing transplanting is another method for paddy rice planting, it is labor saving, but crop performance can be easily affected by windy weather and then results with high plant establishment losses.

In four regions of paddy rice production but Region C, mechanical transplanting has been the dominant technology for paddy rice mechanical planting, contributing to over 80 % of the mechanical planting area, and showed significant rising trend. While the adoption area of mechanical direct seeding and throwing transplanting were observed with a dramatic trend of decrease in China, as shown in **Fig. 3**.

Between 2006 and 2010, In Region A, the adoption ratio of mechanical transplanting (MT) increased by 66 %, the adoption ratio of mechanical throwing transplanting (MTT) decreased by 80 %. And the adoption ratio of mechanical direct seeding (MDS) developed steadily.

In Region B, MT increased from 62 % to 80 %, MDS decreased from 36 % to 14 %, and MTT decreased to 0.06 %.

In Region C, MT doubled, MTT decreased 40 %, however it was still the occupying way of planting and MDS decreased to 0.1 %.

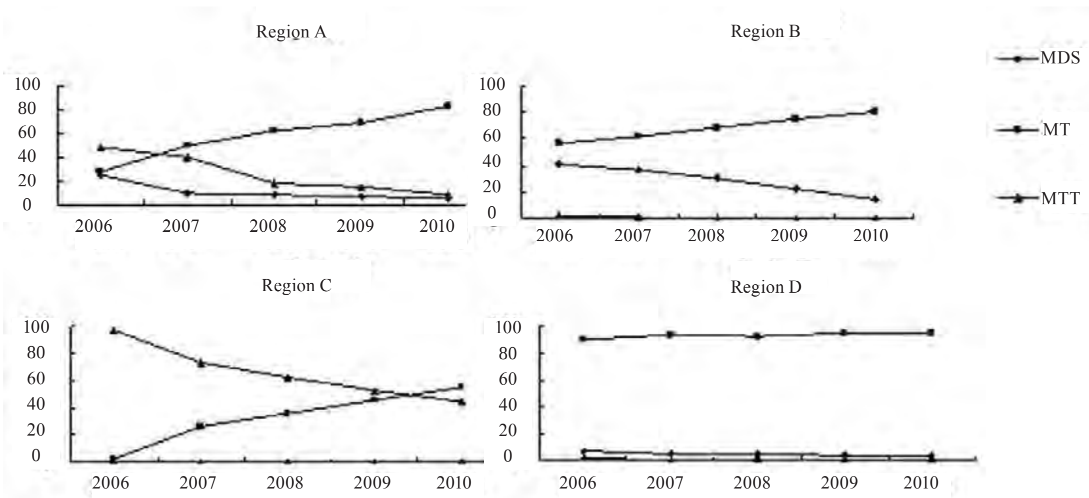
In Region D, MT remained steadily around 95 %, MDS decreased to 3.2 %, and MTT increased to 0.8 %.

For mechanical transplanting, there are machineries available. Four to six rows walking type and riding type paddy rice transplanters are adopted in regions. While, four rows walking type still occupies a larger portion of the machinery.

Plant protection

Timely control of insectpests and disease is an important field operation. The incidence of pest and diseases are greater for paddy rice production, because of the high humidity environment is conductive for their growth. Weeds compete with rice crops for soil nutrients, moisture, light and space. Unless weeds are controlled in time, the crop yields reduce drastically. Machineries used for chemicals application are mainly lever operated knapsack sprayers or hand sprayers for small scale farming. On large farms, motorized mist blowers are commonly adopted. Engine operated and shoulder mounted sprayers are available which are ideal for spraying operations. Since they

Fig. 3 Adoption Ratio of Paddy Rice Planting Technologies in China



are precise operation, good care is required in their operation. In north China, aerial spraying is also adopted for chemical utilization.

Irrigation

Irrigation is import in paddy rice production as sufficient moisture must be maintained in the soil for obtaining the optimum yield. Paddy field irrigation is generally done by basins flooding and simplified pumps. Pressurized irrigation systems are not very popular.

Harvesting

Timely harvesting of cereals crops reduces the risk of weather hazards and clears the field for next operation, especially in Region A. Power operated harvester is the need of the hour to easily harvest the paddy rice to reduce drudgery. Over half of the paddy rice harvesting operation was done mechanically, generally using full-feed combines and four to six rows semi-feed combines. While in small scale fields, two rows semi-feed combines are more popular. Plain sickles which has low capacity and require high cutting operation costs, were used by the farmers where combines were not available.

Threshing

Some regions do not adopt combine harvester, but using cutters and threshers. By this method, losses are quite high, caused by the poor operation quality and low efficiency, which all lead to high timeliness yield loss. Farmers easily get fatigued during threshing operation, especially in double-cropping region due to tropical climate of the harvesting season at where wooden hand operated horizontal and vertical threshers are the commonly used equipments by farmers.

Post harvest operations

Efforts to increase rice production should focus on minimizeing losses that occur during harvesting and postharvest operations like threshing, drying and storage. In north China, when paddy rice is ready to be harvested, the moisture content is low, and dryer is more popular since there are generally large farms. In other regions, farmers tend to follow traditional drying methods. Rice is hulled using hullers, result with high breakage of grains. Uncertainty of rain makes it difficult for open air drying. And paddy rice dryer are beyond the purchase capability of farmers with small size farm.

Constraints of Paddy Rice Mechanization

Complete mechanization of paddy rice field operations has not been achieved, especially for mechanical planting. The development was influenced by many factors. The bottlenecks for paddy rice mechanization development in China include: complicated topography, small farm size, lack of machinery, poor economic condition, and lack of farm roads, etc.

Topography

Topography is one of the dominant limiting factors for mechanization adoption. The use of machinery for paddy field operations could not satisfy the requirements of sloping and hilly land which account for a large proportion of paddy rice production, especially in double cropping area and south western China. Soil type is also a barrier to machinery use in many areas. Some low lying areas are waterlogged, which makes mechanization operation impossible.

Small and scattered land

There is a lot of small and scattered land owned by small individual holdings due to the land policy in China. Most farmers possessed land holdings less than one hectare. Farming on such kind of land is restricted to hand tools and manual technologies. Thus, farmers were unable to use the machineries gainfully. And it takes much time and labor to transport them from one field to another.

Irregular shape of fields

Irregular shape of fields made it difficult to carry out field operations properly. Machinery can not operate efficiently in irregular shape fields, especially when it came to the corners. Farmers thought that the problem can be solved by introducing joint farming or farming on cooperatives leading to farm holding size increase. Land consolidation has been done by the Department of Revenue collaborating with the Department of Agricultural in some regions, farm roads, irrigation systems, irrigation channel, and drainage channels had been put into consideration.

Poor Economic Condition of Farmers

Due to poor economic condition of farmers, in spite of the willingness to own machinery, they were unable to, as purchasing power is not high enough. The increased cost of fuel and machinery hiring rate also make it unattractive for farmers to hire machines. Average income of farmers was CNY 5,153.17 (US$ 780.78), which is far beyond the ability to purchase the machine. The sales price, for example, of a Yanmar Ce-2M semi-feed 2 rows combine harvester manufactured in China is about CNY 116,500 (US$ 17,651). If the farmer applies for a 10 year agricultural loan which has a interest rate of 4.2 %, they need to pay back CNY 17,579 (US$ 2,663) per year, which is 85.3 % of the total annual net income of a 4 member's family (Lijun Xu, 2011).

Lack of farm roads

Farm roads are the backbone of agricultural mechanization. The basic source of energy input to the field is still transported by tractors which run on roads, all the implements and machinery need farm roads to go to the field. This was one of the most important factors, prohibiting farm mechanization. While in China, farm roads are generally small roads which only allow farmers walk on. In southwest China, common farm roads are less than one meter wide and make it impossible to run tractor driven machinery.

Sometimes weather condition also restricts machines usage. Prolonged rainy weather in harvesting season may affect timeliness harvesting and other activities later in the season. Availability of farm machinery is also a major limiting factor. Domestic manufacturers are lack of technological capability and imported machineries are too expensive to purchase.

Conclusion

It is found that the mechanical level of paddy rice production is still low in China, and the development status in four regions was different from each other.

Among the field operations, mechanical level of tillage is the highest, mechanical level of planting is the lowest.

Among mechanical planting technologies, transplanting is the most dominant technology adopted, contributing to 80 % of the mechanical planting area, and shown a significant trend of development.

Among the factors limiting the development of paddy rice production mechanization, topography is one of the most dominant factors, which can hardly be improved. Small farm size and irregular land, and lack of farm roads set up barriers for the development of paddy rice production mechanization; these factors can be improved through land consolidation, circulation or other countermeasures.

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■■

Development and Performance Evaluation of Two Row Subsoil Organic Mulch Cum Fertilizer Applicator

by
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Abstract

Deep tillage loosens the subsoil layers that remain moist. Presence of organic mulch material in the subsoil could also make the subsoil biologically active and enhance the root growth in to subsoil layers. For precise application of the limited available organic mulch in subsoil soil at desired application rate and depth, two row subsoil organic mulch cum fertilizer applicator has been developed. The performance of the prototype two row subsoil coir pith mulcher was evaluated in field and compared with subsoiling and control plots. The composted coir pith mulch registered 14.1, 18.5, 2.7, 8.3, 18.6 and 16.6 % higher plant height, boll formation, root length, root spread, root volume and yield respectively. The deep loosening and placement of mulch in the subsoil layer just below the plant rows resulted in reduction of soil strength which helped the plant roots to penetrate deep into this layer and proliferate in vertical subsoil trenches. The recompaction of subsoil trenches is prevented due to the presence of raw and composted coir pith mulch. The soil moisture content in the composted coir pith mulched plot, raw coirpith mulched plot and subsoiled plot were consistently higher than that of the control plots. The effect of mulching is predominant when placed at medium depth of 250-350 mm and deeper depth of 350-450 mm when compared to shallow depth.

Introduction

Crops grown under rainfed conditions are prone to water stress, owing to rapid loss of soil moisture and development of mechanical impedance to root growth. The stress can be alleviated by enlarging rooting volume in the soil and/or by regulating the supply of soil moisture. Incorporated residue can improve soil drainage and reduce bulk density. Mulches have been found to decrease soil moisture losses by reducing soil temperature and evaporation, promoting favourable soil biotic activities, reducing hard soil setting and contributing plant nutrients. Subsoil placement of mulch would prevent it from dispersed during subsequent tillage operations. Controlled application rate and depth of placement in the field can contribute to make management of organic manure a more technologically and economically interesting alternative for soil and crop growth. The performance evaluation of two row subsoil coir pith mulcher for cotton in comparison with subsoiling and no mulching is reported.

Review of literature

In row subsoiling increased seed cotton yield by 212 kg ha^{-1} compared to non-subsoiled plots. An additional deep tillage operation with a paratill plough increased the seed cotton yield about 516 kg ha^{-1} (Garner *et al*., 1989). A yield increase in cotton from 12 to 41 % corresponding to subsoil compacted silt loam soils was reported by McConnell *et al*. (1989). Subsoiling increased yield of corn by 24 % and the yield increase was attributed to improved root growth in less compact soil (Adeoye and Mohammed, 1990). Subsoiling is often used to combat soil compaction and reduce soil strength to levels that allow for root development and growth (Garner *et al*., 1987; Vepraskas *et al*., 1997; Raper, 2005). This tillage process provides increased rooting depth to with stand short term drought conditions prevalent during growing season. The annual subsoiling depth is between 0.3 m and 0.5 m. The depth of tillage is often chosen based on average needs of soil and the capability of the tractor and implement.

Methods and Materials

The two row subsoil organic mulch cum fertilizer applicator was built around a chisel plough. The functional components include chisel plough, manure and fertilizer hopper with metering device and agitator for the organic manure. Two chisel plough bottoms were mounted on a main frame with adjustable rail through which the spacing can be adjusted to suit the row spacing of crops. The mainframe was attached to the tractor through three point linkage. Two trapezoidal shapes feed hoppers are mounted on the main frame for holding the organic manure. An agitator is provided in the manure hopper to prevent clogging of the manure. The manure form the hopper is metered by a screw auger assembly and dropped into the furrow opened by the furrow wings attached with the chisel shank. Two trapezoidal shapes feed hoppers are attached with the manure hopper to hold the fertilizer. The fertilizer is metered by a stationery opening device and placed above the manure. The manure and fertilizer metering devices are driven by a ground wheel unit. The agitator is driven by PTO of the tractor through chain and sprocket transmission system. The unit is suitable for accurate and controlled application of organic manure/mulch directly below the root zone of crop. It helps in improving the soil nutrient use efficiency, crop yield and soil quality. Adjustable spacing between furrows enables the use at different row spacing. The cost of the unit is Rs. 50,000. The unit can cover one ha per day. The specifications of the two row subsoil organic mulch cum fertilizer applicator are furnished in **Table 1**.

The front and side view of tractor operated two row subsoil mulcher is shown in **Figs. 1** and **2** respectively. The idle and operational view of the unit is shown in **Figs. 3** and **4** respectively. For application of the recommended level of 20 t ha^{-1} mulch, a speed reduction ratio of 1.8: 1 and 1.9: 1 between the intermediate shaft and auger shaft was provided for raw coir pith and com-

Table 1 Specifications of two row subsoil organic mulch cum fertilizer applicator

Details	Value
Over all dimensions, (L × B × H) mm	1710 × 2040 × 1360
Size of main frame, (L x B) mm	1600 × 615
Hitch	Category I and Category II
No. of chisel plough bottom	2
No. of cross rails	2
Distance between shank, mm	Adjustable from 550 to 1200
Number of organic manure hoppers	2
Number of fertilizer hoppers	2
Shape of hoppers	Trapezoidal
Volume of hopper, m^3	0.2
Type of metering mechanism for organic mulch	Auger feed
Type of metering mechanism for fertilizer	Stationery opening
Volume of hopper, m^3	0.04
Drive to agitator	From PTO shaft through sprocket and chain
Drive to auger and fertilizer metering device	From Ground wheel through sprocket and chain
Diameter of the ground wheel, mm	600

Fig. 1 Two row subsoil organic mulch cum fertilizer applicator (Front view)

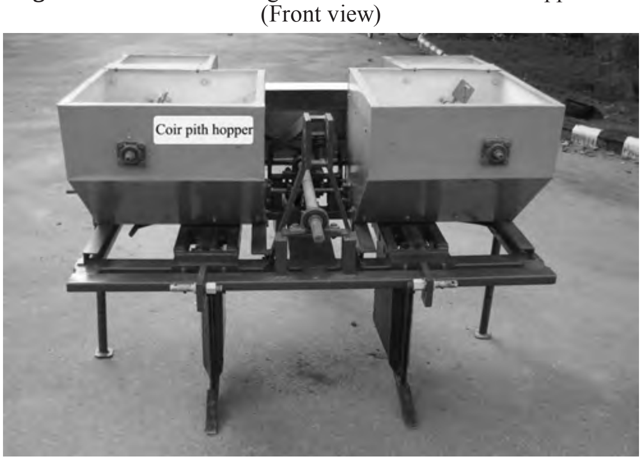
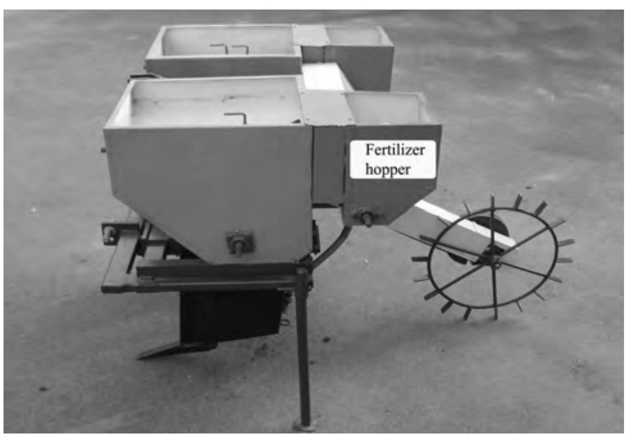


Fig. 2 Two row subsoil organic mulch cum fertilizer applicator (Side view)



posted coir pith respectively and the prototype was calibrated. The performance of the prototype two row subsoil coir pith mulcher was evaluated in field No. 36 E in Eastern block of Tamil Nadu Agricultural University, Coimbatore. A total number of 24 experiments were conducted in the experimental plot with optimized levels of variables. The size of the each plot was 6 × 3 m. The treatments for the evaluation of prototype two row subsoil coir pith mulcher are furnished below.

Treatments: 4
T_1: Composted coir pith mulch (20 t ha^{-1} and 350-450 mm depth)
T_2: Raw coir pith (20 t ha^{-1} and 350-450 mm depth)
T_3: Subsoiling (without mulch and 350-450 mm depth)
T_4: Control (No mulch)
Replications: 6

The raw and composted coir pith was applied at optimized level of 350-450 mm depth and 20 t ha^{-1} and application rate respectively. The cotton seeds were sown manually at row-to-row spacing of 750 mm and plant-to-plant spacing of 300 mm. The performance of the prototype two row subsoil mulcher was compared with subsoiling and control (without mulch). The evaluational parameters are crop response viz. root length, root spread, root volume and yield.

Fig. 3 Two row subsoil organic mulch cum fertilizer applicator fitted with trcator

Fig. 4 Two row subsoil organic mulch cum fertilizer applicator (Operational view)

Results and Discussion

The difference in plant height between the control and mulched plots was clearly exhibited in **Fig. 5**. The plant height in composted coir pith, raw coir pith and subsoiled treatment plots was increased by 69.3, 54.8 and 46.4 % over control. This may be attributed to the proliferation of the root resulting in a greater absorption of nutrient and water from the soil, causing higher plant height in mulched and subsoiled treatments (Taylor and Klepper, 1978). The effect of mulching and subsoiling on ball formation in cotton crop during the maturity stage of the cotton is depicted in **Fig. 6**. It is inferred that the ball formation in the composted coir pith, raw coir pith and subsoiled treatment plots was increased by 64.1, 38.5 and 26.5 % over control. The subsoil application of raw and composted coir pith significantly influenced the root length as seen from the **Fig. 7**. The root length in the composted coir pith, raw coir pith and subsoiled treatment plots was 32.4, 29.0 and 43.2 % higher over control. The root zone environment provided by the mulched plot was characterized by reduced mechanical impedance, more organic matter content and high moisture availability. This helped the root to grow and proliferate. The examination of the plants excavated form the four treatments (**Fig. 8**) clearly showed that there was marked difference in root development between these four treatments. The major portions of the roots were formed along the plane of the vertical mulch which clearly indicated the development of root in the trenches loosened by the mulcher. Subsoiling can mechanically aerate the soil at subsoil layers that promotes better infiltration and absorption, and encourages crop root development (Xu and Mermoud, 2001).

The effects of mulching and subsoiling on root spread after the harvest of the cotton crop is depicted in **Fig. 9**. It is seen that the root spread was maximum of 471 mm in composted coir pith followed by 434 mm in raw coir pith and 387 mm in subsoiled treatment plots. The better root spread in composted coir pith and raw coir pith mulched treatment plots was reflected with 21.4 and 12.1 % higher values over subsoiling. Among the mulch materials, composted coir pith mulch was superior in registering 8.3 % more root spread than raw coirpith mulch. The beneficial effect of composted coir pith was due to the combined influence of greater soil moisture availability and nutrient supply capacity created by composted coir pith application.

The effect of mulching and subsoiling on root volume after the harvest of the cotton crop is depicted in **Fig. 10**. A similar tend as observed in root spread is exhibited. The root volume was increased by 36.6 and 15.3 % for composted coir pith and raw coir pith mulched treatment plots over subsoiling. The root volume of cotton was 12.1 % more in composted coir pith mulch when compared to raw coir pith mulch. The improvement in root growth is attributed to a favourable soil physical environment created by the addition of composted coir pith mulch.

The soil moisture status in the treatment plots during the growth period of cotton is depicted in **Fig. 11**. At shallow depth of 150-250 mm (D_1) there was not much variation in the soil moisture content values between the four treatments. But the soil moisture content in the composted coir pith mulched plot (T_1), raw coirpith mulched plot (T_2) and subsoiled plot without mulch (T_3) was consistently higher than that of the control plots medium depth of 250-350 mm (D_2) and deeper depth of 350-450 mm (D_3) during the growth period of crop. The effect of mulching was predominant at medium and deeper depth of placement and compared to shallow depth of placement. It is clear that the deep ploughed and mulched plots absorbed largest amount of water over subsoiling and control.

Availability of soil moisture in deeper layers during later growth stages of crops was more in mulched than subsoiled and unmulched plots. Unmulched plots stored the least amount of soil moisture. No significant difference in soil moisture storage was found between raw and composted coir pith mulch. Deeper and denser rooting helped the crop to extract more water from the soil (Chancy and Kamprath, 1982 and Arora *et al*., 1991) and provided an interim relief against the development of water stress.

The effect of mulching and subsoiling on yield of cotton is depicted in **Fig. 12**. It is observed that the crop yield was the highest in composted coir pith mulched treatment. The crop yield in composted coir pith mulch, raw coir pith mulch and subsoiled treatment plots was 116.7, 85.7 and 66.7 % higher over control (No mulch).

The crop yield was higher by 30.0 and 11.4 % in composted coir pith and raw coir pith mulched treatment plots over subsoiling. The composted coir pith mulch recorded 16.8 % increased cotton yield than raw coir pith mulch. Applications of composted coir pith increased the soil moisture content, improved the availability and uptake of nutrients and equally promoted the growth and yield of cotton. The influence of root proliferation and associated yield was more pronounced in composted coir pith mulched plot.

Conclusions

A tractor operated two row subsoil coir pith mulcher has been developed for application of coir pith uniformly in the subsoil at desired rate of application and depth of placement. The performance of the prototype two row subsoil coir pith mulcher was evaluated in field condition and compared with subsoiling and control plots. From the analysis of results, the conclusions drawn are:

• Plant height in composted coir pith, raw coir pith and subsoiled treatment plots increased by 69.3, 54.8 and 46.4 % over control (No mulch). Plant height increased by 15.6 and 5.7 % in composted coir pith and raw coir pith mulched treatment plots over subsoiling. Composted coir pith mulch registered 14.1 % higher plant height than raw coir pith mulch.

• Boll formation in the composted coir pith, raw coir pith and subsoiled treatment plots increased by 64.1, 38.5 and 26.5 % over control. The number of balls per plant increased

Fig. 5 Effect of mulching and subsoiling on plant height

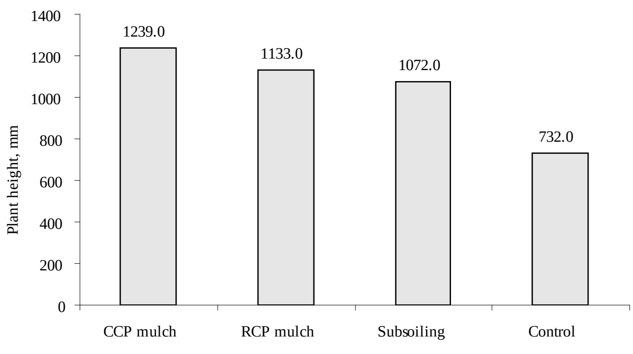
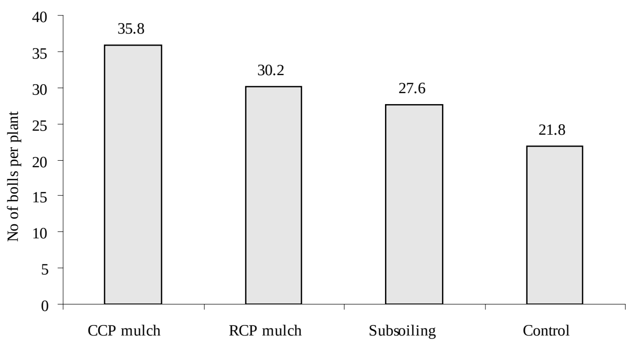


Fig. 6 Effect of mulching and subsoiling on boll formation



by 29.4 and 9.4 % for composted coir pith and raw coir pith mulched treatment plots over subsoiling. The composted coir pith mulch proved its superiority by recording 18.5 % higher number of balls than raw coir pith mulch.

• Subsoiled plot recorded the maximum root length of 534 mm than composted coir pith mulch (494 mm) and raw coir pith mulch (481 mm) treatment plots. The root length in the composted coir pith, raw coir pith and subsoiled treatment plots was 32.4, 29.0 and 43.2 % higher over control.

• Better root spread in composted coir pith and raw coir pith mulched treatment plots was reflected with 21.4 and 12.1 % higher values over subsoiling. Composted coir pith mulch registered 8.3 % higher root spread than raw coir pith mulch.

• Root volume was increased by 36.6 and 15.3 % for composted coir pith and raw coir pith mulched treatment plots over subsoiling. The root volume of cotton was 12.1 % more in composted coir pith mulch when compared to raw coir pith mulch.

• Yield in composted coir pith mulch, raw coir pith mulch and subsoiled treatment plots was 116.7, 85.7 and 66.7 % higher over control. The yield is higher by 30.0 and 11.4 % in composted coir pith and raw coir pith mulched treatment plots over subsoiling. The composted coir pith mulch recorded 16.8 % increased cotton yield than raw coir pith mulch.

• The deep loosening and placement of mulch at the subsoil layer just below the plant rows resulted in reduction of soil strength which helped the plant roots to penetrate deep into this layer and proliferate in vertical subsoil trenches. The recompaction of

Fig. 8 Variation in root length and spread of cotton in treatment plots

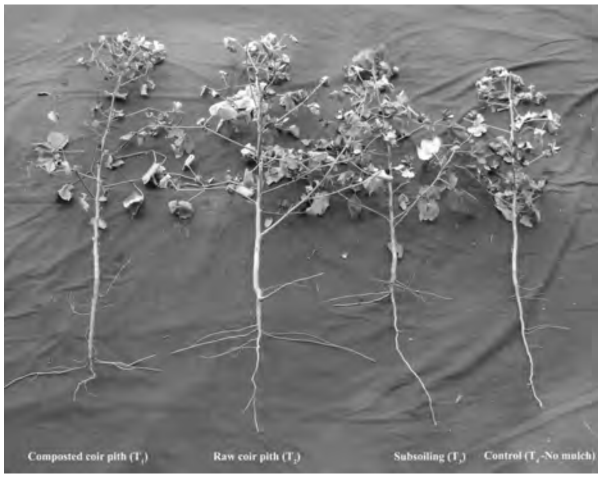


Fig. 7 Effect of mulching and subsoiling on root length

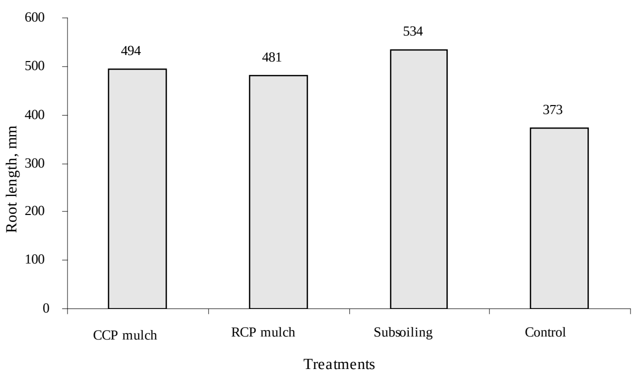


Fig. 9 Effect of mulching and subsoiling on root spread

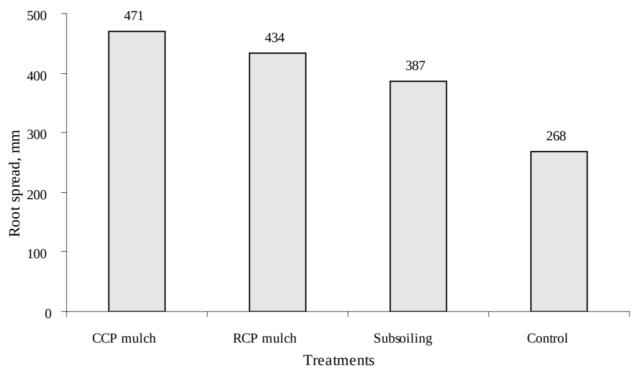


Fig. 10 Effect of mulching and subsoiling on root volume

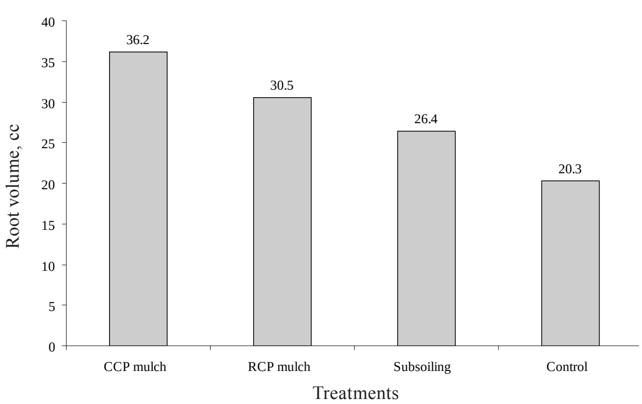
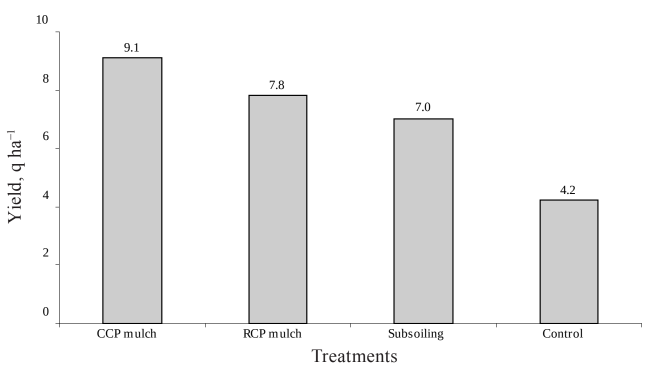


Fig. 12 Effect of mulching and subsoiling on yield



subsoil trenches was prevented due to the presence of raw and composted coir pith mulch.

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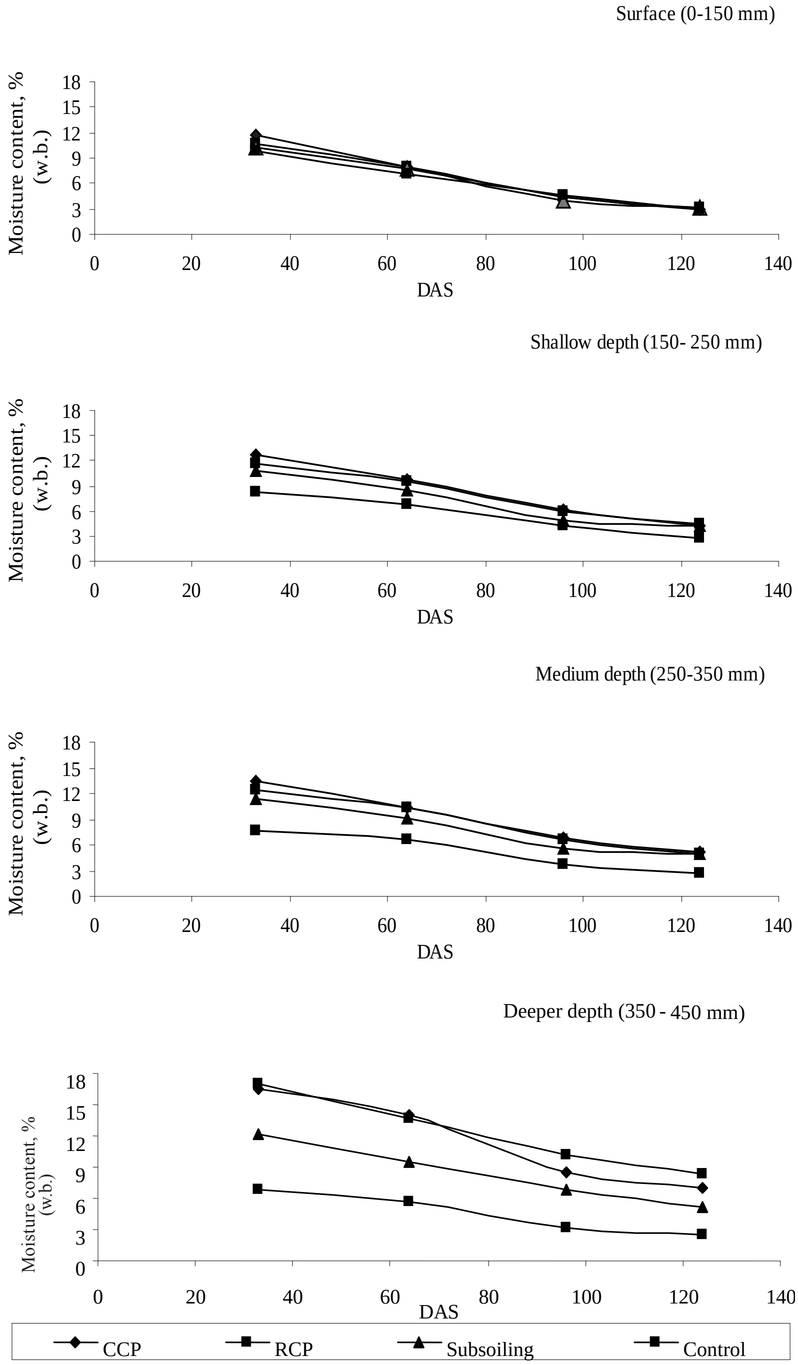
Fig. 11 Soil moisture status for entire growth period of crop



Studies on Utilization of Denatured Ethanol in Small Constant Speed Petrol Start Kerosene Run Type Different Compression Ratio SI Engines

by

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Abstract

The study was conducted to assess the suitability of denatured ethanol of different proofs as a fuel in place of kerosene in petrol start kerosene run type small spark ignition engines used in India. In this study, performance test of three different compression ratio Honda make petrol start kerosene run engines viz. GK200 model (CR 4.5: 1), GK300 model (CR 4.8: 1) and G300 model (CR 6.5: 1) was done on denatured ethanol of 200º, 190º, 180º and 170º proof and kerosene (base fuel). The observed results of experiment indicated that the different denatured ethanol proofs were found to have similar power producing capabilities as kerosene. Fuel consumption, brake thermal efficiency and bsfc were found higher on denatured ethanol poof than kerosene. Results also indicate that higher the compression ratio better is the brake thermal efficiency and lesser brake specific fuel consumption. In addition, emission of UBHC was less, whereas NOx was more in denatured ethanol different proof than kerosene. The 1,800 proof denatured ethanol is recommended for use in engines.

Introduction

Apart from the problem of scarcity, the petro based fuels with their increased use have raised the level of pollutants in the atmosphere to such a large extent that combustion generated pollution has now become a matter of great concern. In addition to that petroleum products (32.8 %) included in topmost principal commodity in Indian total imports during 2008-09 (April-February). Further, during 2008-09 imports increased to Rs. 1,305,503 from the level of Rs. 1,012,312 crore in 2007-08 registering growth of 29.0 % in rupee terms (India, 2010). This clearly indicates the burden of import and out flow of foreign exchanges for petroleum products. Through the reducing petroleum resources, increasing prices and pollution norms have necessitated the search for renewable alternate fuels.

In alternative liquid fuels, alcohols are more popular and use of ethyl alcohol lowers overall emission as its use reduces emission of CO, particulate matter, cancer causing benzene and butadiene to a very high level. Ethanol blends dramatically reduce emission of HC, which is major contributor to the depletion of the ozone layer; reduces net carbon dioxide emission up to 100 % (Lakshmanan, 2005). Further, it is derived from renewable biomass sources and expected to improve Indian farmer conditions because ethanol is primarily derived from sugarcane in India. In addition to that gasohol (10:90 of alcohol: gasoline) is a commercial fuel in over thirty-five countries including USA, Canada and France. Due to lower heating value of ethanol than petro fuels there is reduction in power output from engine but at the same time it is having higher octane number then gasoline. This problem can be addressed with the use of higher compression ratio engines.

In agriculture sector and for domestic use small petrol start kerosene run engines are being promoted. Because manufacturing and burning of ethanol do not increase green house effect and for achieving Bharat III and IV emission standards it is obligatory to use ethanol by taking advantage of low emission property in spark ignition engines.

Due to higher octane number, a hike in compression ratio increases power output of engine without knocking so this will do great deal to improve engine performance and economy. However, it is essential to study the effect using aqueous ethanol on engine needs to establish its feasibility.

In light of the above facts, a research work was undertaken on the utilization of denatured anhydrous and aqueous ethanol in different compression ratio, constant speed spark ignition engines with the objective: To study the performance of constant speed SI engines having different compression ratio on denatured anhydrous and denatured aqueous ethanol of different proofs (**Table 1**).

Acknowledgments

The financial assistance provided through the ICAR Scheme on 'Studies on Combustion Characteristics of Alcohol-Diesel Micro Emulsions and Denatured Alcohol as Stationary CI & SI Engine Fuel' is thankfully acknowledged.

Materials and Methods

The experiments were conducted in the Bio Energy Technology Laboratory of the Department of Farm Machinery and Power Engineering, College of Technology, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India.

Experimental Set-up

Three engines of Honda make, four stroke, petrol start kerosene run type were selected for the fuel consumption test and to study the effect of compression ratio. The specification of the selected engines is shown in **Table 1**.

The schematic diagram of the experimental setup is shown in **Fig. 1**. It consists of the test engine coupled to an eddy current dynamometer along with controller. A SAJ-Froude make, EC-15 model dynamometer was used to load the engine.

The experimental set-up also consisted of a SAJ-Froude make, SFV-75 model electronic volumetric fuel consumption measuring unit. Exhaust emissions were drawn with the help of a steel tube and PVC gas suction pipe using an air pump. The discharge of air pump was taken to NO, HC and NO_2 analyzers respectively. The performance of the engine was evaluated on five different fuel types and six levels of brake load.

The fuel consumption test as per IS: 7347-1974 was conducted to evaluate performance of engines. In order to carry out fuel consumption test, initially an engine was started on petrol and then run for a couple of minutes. The engine operation was then switched on to the selected fuel for the study at no load condition. The engine on selected fuel was further run for a minute under no load condition for warming up. After warm up, the engines were gradually loaded up to 110 % load to stabilize its operation. Once, the engine operation was stabilized, it was brought to full (100 %) load condition. The full load on the engine corresponds to the state of the engine when it is developing the continuous rated brake power at the rated speed. Before starting the test, the engine was loaded to full load and its speed was set to rated speed ± 10 rpm. The corresponding torque as indicated by the dynamometer at full load was then divided to obtain no load, 25, 50, 75 and 110 % load on the engine. The fuel consumption test of the engine on different fuels was then carried out at the selected loads. The experiment with each fuel type was replicated three times and the average value of different parameters measured was taken for analysis.

Results and Discussion

Performance evaluation of engines in respect of brake horsepower, fuel consumption, brake specific fuel consumption, brake thermal

Fig. 1 Schematic diagram of the experimental setup for engine testing

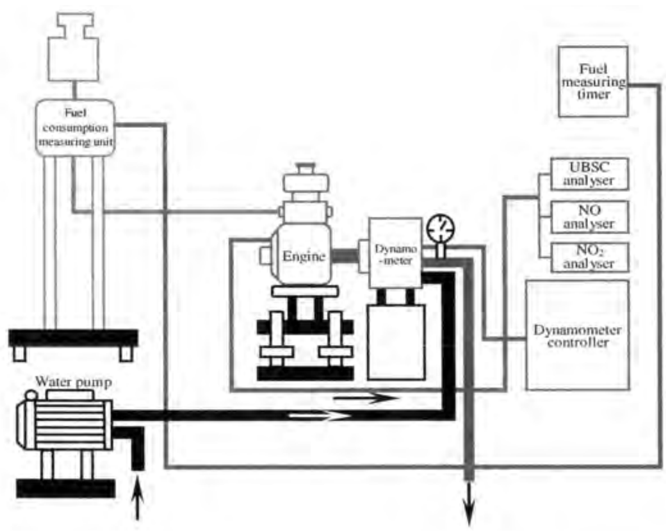


Table 1 Denatured anhydrous and aqueous ethanol prepared for the test

Ethanol Proof (°)	Fuel Constituents (%)		
	Ethanol	Distilled Water	Kerosene
200°	90.0	0.0	10
190°	85.5	4.5	10
180°	81.0	9.0	10
170°	76.5	13.5	10

efficiency were carried out under different load conditions as per IS: 7347-1974.

Brake Horsepower

The brake horsepower developed and the corresponding engine speed of different engines on kerosene and different denatured ethanol proofs is shown in **Fig. 2**.

The performance of the GK200 engine on kerosene and denatured ethanol of 2000, 1900, 1800 and 1700 proof indicates that at 100 % load the engine developed same brake power of 2.24 kW and corresponding engine speeds were 3607, 3608, 3606, 3607 and 3597 rpm respectively. It is evident that the fuel energy input increased with increase in engine load on all fuel types. The fuel energy input to the engine when running on different ethanol proofs at full load was found to be 26.2, 17, 15.3 and 13.7 % less on 2000, 1900, 1800 and 1700 proof in comparison to kerosene.

The performance of the GK300 engine on kerosene and denatured ethanol of 2000, 1900, 1800 and 1700 proof indicates that at 100 % load, the engine developed brake power of 2.94, 2.95, 2.94, 2.95 and 2.94 kW and corresponding engine speeds were 3594, 3606, 3602, 3607 and 3603 rpm respectively. The fuel energy input to the engine when running on different ethanol proofs at full load was found to be 26.4, 18.5, 8.3 and 0.8 % less on 2000, 1900, 1800 and 1700 proof in comparison to kerosene.

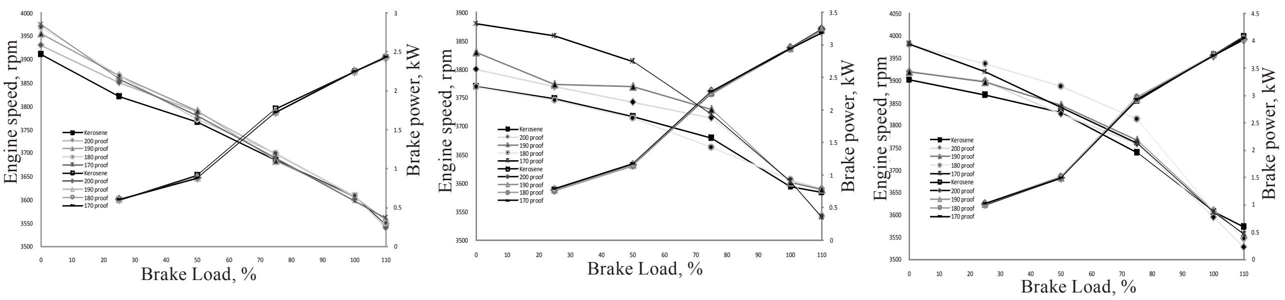
It is evident from the table that the G300 engine was set to run at the rated engine speed at full load (100 %) condition when developing its rated brake power of 3.73 kW under all fuel types. The performance of the engine on kerosene and denatured ethanol of 2000, 1900, 1800 and 1700 proof indicates that at 100 % load the engine developed brake power of 3.74, 3.72, 3.74, 3.74 and 3.73 kW and corresponding engine speeds were 3607, 3594, 3609, 3607 and 3605 rpm respectively. It is evident that the fuel energy input increased with increase in engine load on all fuel types. The fuel energy input to the engine when running on different fuel types at full load was found to be 21.5, 20.7, 19.6 and 15.6 % less on 2000, 1900, 1800 and 1700 proof in comparison to kerosene.

Based on the above results it can be said that, in general, the ethanol proofs used had the similar power producing capability as kerosene fuel and the energy input by denatured ethanol of 2000, 1900, 1800 and 1700 proof was lesser than the kerosene. This could be attributed to the fact that the brake thermal efficiency of the engines on different ethanol proofs was higher than kerosene despite of the reason that consumption of ethanol proofs was more and their heat content was less than the kerosene. It has been further observed that engine selected for the experiment developed the designated rated power on both anhydrous and aqueous ethanol proofs despite of having different compression ratio.

Fuel Consumption

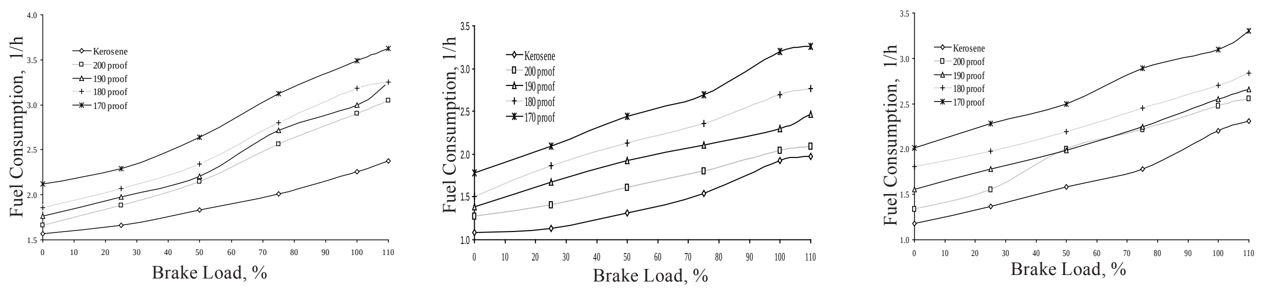
The fuel consumption of different engines on kerosene and denatured

Fig. 2 Brake horse power and engine speed of different engines at rated speed on different fuels



(i) GK200 model (ii) GK300 model (iii) G300 model

Fig. 3 Fuel consumption of different engines at rated speed on different fuels



(i) GK200 model (ii) GK300 model (iii) G300 model

ethanol of different proofs at various loads is shown in **Fig. 3**. It is evident from the figure that fuel consumption of the engines gradually increased with increase in brake load and was observed to be the highest at 110 % load on all the selected fuel types.

The fuel consumption of the GK200 engine at full load (100 % load) when the engine developed its rated power (2.24 kW) was found to be 1.62, 1.72, 1.97, 2.1 and 2.34 l/h on kerosene and denatured ethanol of 2000, 1900, 1800 and 1700 proof respectively. This reveals that the engine when developing its rated power had 6.2, 21.6, 29.6 and 44.4% higher consumption of 2000, 1900, 1800 and 1700 proof denatured ethanol respectively in comparison to kerosene.

The fuel consumption of the GK300 engine at full load (100 % load) when the engine developed its rated power (2.94 kW) was found to be 1.93, 2.04, 2.3, 2.7 and 3.2 l/h on kerosene and denatured ethanol of 2000, 1900, 1800 and 1700 proof respectively. This reveals that the engine when developing its rated power had 5.7, 19.2, 39.9 and 65.8 % higher consumption of 2000, 1900, 1800 and 1700 proof denatured ethanol respectively in comparison to kerosene.

The fuel consumption of the G300 engine at full load (100 % load) when the engine developed its rated power (3.73 kW) was found to be 2.2, 2.48, 2.55, 2.7 and 3.1 l/h on kerosene and denatured ethanol of 2000, 1900, 1800 and 1700 proof respectively. This reveals that the engine when developing its rated power had 12.7, 15.9, 22.7 and 40.9 % higher consumption of 2000, 1900, 1800 and 1700 proof denatured ethanol respectively in comparison to kerosene.

The higher fuel consumption of the engine on denatured ethanol of different proof as compared to kerosene was due to the fact that heat of combustion of proofs was less than that of kerosene as indicated in **Fig. 4.3**. Further, higher fuel consumption of lower proof ethanol could also be attributed to the leaning effect of water as the aqueous ethanol of 1900, 1800 and 1700 proof had 4.5, 9.0, and 13.5 % water content in them compared to anhydrous ethanol (2000 proof).

Brake Specific Fuel Consumption

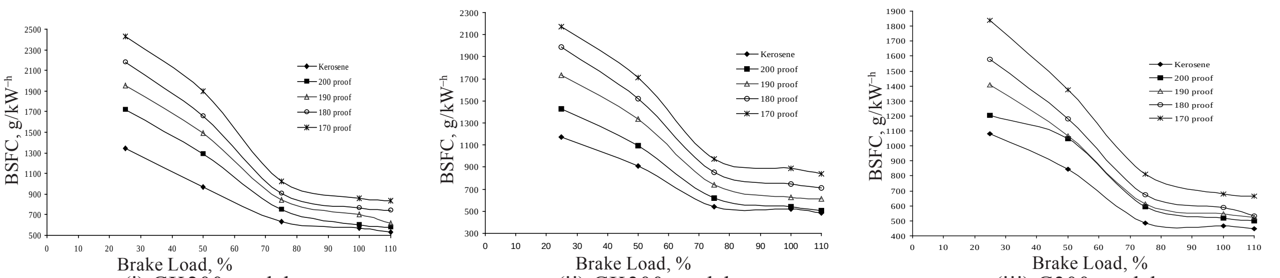
The change in brake specific fuel consumption with load of different engines on kerosene and denatured ethanol of different proof at various loads is shown in **Fig. 4**. It is evident from the figure that brake specific fuel consumption of the engines gradually decreased with increase in brake load and was observed to be the lowest at 110 % load on all the selected fuel types. The manufacturer of the engines has specified the brake specific fuel consumption of the engine on kerosene as 600 g/kW^{-h}.

The brake specific fuel consumption of the GK200 engine on kerosene fuel at full load was found to be 572.3 g/kW^{-h}. The brake specific fuel consumption of all the engines at full load (100 % load) when the engine developed its rated power (2.94 kW) was found as 598.4, 702.6, 762.4 and 857.3 g/kW^{-h} on 2000, 1900, 1800 and 1700 proof denatured ethanol respectively. This reveals that the brake specific fuel consumption of the engine was 4.6, 22.8, 33.2 and 49.8 % higher on 2000, 1900, 1800 and 1700 proof denatured ethanol respectively compared to kerosene when developing its rated brake power.

Table 2 Specification of engines selected for fuel consumption test

Make	Honda		
Model	GK200	GK300	G300
Rated power (hp/kW)	3/2.24	4/2.94	5/3.73
Rated engine speed (rpm)	3,600	3,600	3,600
Compression ratio	4.5: 1	4.8: 1	6.5: 1
Number of cylinder	1	1	1
Bore (mm)	67	76	76
Stroke (mm)	56	60	60
Displacement volume (cc)	197	272	272
Max torque (kg.m/rpm)	0.8/2,500	1.26/2,500	1.41/2,500
Cooling system	Air cooled	Air cooled	Air cooled
Starting system	Recoil start	Recoil start	Recoil start
Standard Ignition timing (fixed)	200 BTDC	200 BTDC	200 BTDC

Fig. 4 Brake specific fuel consumption at full load of different compression ratio engines on different fuels



(i) GK200 model (ii) GK300 model (iii) G300 model

The brake specific fuel consumption of the GK300 engine on kerosene at full load was found to be 519.9 g/kW^{-h}. The brake specific fuel consumption of the engines at full load (100 % load) when the engine developed its rated power (2.94 kW) was found as 540.8, 625.0, 746.8 and 890.9 g/kW^{-h} on 2000, 1900, 1800 and 1700 proof denatured ethanol respectively.

This reveals that the brake specific fuel consumption of the engine was 4.0, 20.2, 43.6 and 71.4 % higher on 2000, 1900, 1800 and 1700 proof denatured ethanol respectively compared to kerosene when developing its rated brake power.

The brake specific fuel consumption of the G300 engine on kerosene at full load was found to be 465.1 g/kW^{-h}. The brake specific fuel consumption of the engines at full load (100 % load) when the engine developed its rated power (2.94 kW) was found as 519.8, 545.2, 588.2 and 680 g/kW^{-h} on 2000, 1900, 1800 and 1700 proof denatured ethanol respectively. This reveals that the brake specific fuel consumption of the engine was 11.8, 17.2, 26.5 and 46.2 % higher on 2000, 1900, 1800 and 1700 proof denatured ethanol respectively compared to kerosene when developing its rated brake power.

It is evident from the figures that the brake specific fuel consumption of the engines gradually decreased with increase in brake load due to the fact that the brake horsepower of the engine increased with increase in brake load. The lowest brake specific fuel consumption on denatured ethanol was observed on anhydrous ethanol of 2000 proof. This is obvious due to the reason that it has higher heat value than the aqueous ethanol. Further, comparison amongst the aqueous denatured ethanol indicates that with an increase in water content, a noticeable increase in brake specific fuel consumption was observed and it was considerably high on 1700 proof denatured ethanol. The comparison of brake specific fuel consumption of the engines at full load indicates that G300 model engine having compression ratio of 6.5: 1, the highest among the selected engines had the lowest brake specific fuel consumption. This is due to the fact that brake specific fuel consumption at full load of different compression ratio engines on different fuels combustion efficiency of a spark ignition engine is better at higher compression ratio because of higher rise in cylinder pressure and temperature.

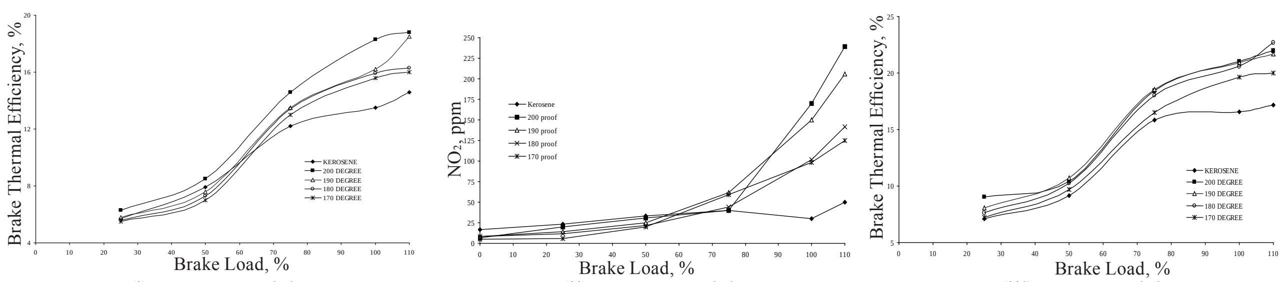
Brake Thermal Efficiency

The change in brake thermal efficiency of different engines on kerosene and denatured ethanol of different proof at various loads is shown in **Fig. 5**. It is evident from the figure that brake thermal efficiency of the engines gradually increased with increase in brake load and was observed to be the highest at 110 % load on all the selected fuel types.

The brake thermal efficiency of the GK200, GK300 and G300 engine at full load (100 % load) when it developed its rated power (2.24 kW) was found to be 13.5, 18.3, 16.2, 15.9 and 15.6 %; 14.8, 20.2, 18.2, 16.2 and 15.0 %; and 16.6, 21.0, 20.9, 20.6 and 19.6 % on kerosene and denatured ethanol of 2000, 1900, 1800 and 1700 proof respectively. These observations indicate that the brake thermal efficiency of engines was more on denatured ethanol than the kerosene. This finding is in line with that of Mathur and Sharma (2001) which indicates that small increment of increased thermal efficiency on ethanol fuel in comparison to gasoline occurs mainly due to evaporative cooling effect of alcohol causing reduction in specific heat of gases as well as the heat losses. The results further reveal that the brake thermal efficiency of the engines was highest on anhydrous ethanol and it gradually decreased with increase in water content in ethanol and was lowest on 1700 proof denatured ethanol. Thus is in accordance with the findings of Chandan Kumar (2002). In addition to that the effect of compression ratio on brake thermal efficiency of engines indicate that the G300 model engine having highest compression ratio of 6.5:1 had the highest efficiency as evident from **Fig. 5**. Further, the efficiency was higher on ethanol than the kerosene and with an increase in water content in ethanol it decreased. This observation can be correlated with the findings of Mathur and Sharma (2001) as indicated above.

The emission of hydrocarbon (HC) nitric oxide (NO) and NO_2

Fig. 5 Brake thermal efficiency at full load of different compression ratio engines on different fuels



(i) GK200 model (ii) GK300 model (iii) G300 model

from the engine at different loading conditions on selected fuel types was measured. The emission of HC and NO from a spark ignition engine may be around 0.05 to 0.1 % and 400 to 2,750 ppm respectively (Mathur and Sharma, 2001).

Emission of Hydrocarbon

The change in emission of hydrocarbon from different engines on kerosene and denatured ethanol of different proof at various loads is shown in **Fig. 6**.

It has been observed that the emission of hydrocarbon from the GK200 engine on kerosene ranged between 2.58 to 3.86 % under different loading condition. The hydrocarbon emission from the engine was observed in the range of 1.12 to 2.39, 0.27 to 0.58, 0.02 to 1.42 and 1.26 to 2.43 % on denatured ethanol of 2000, 1900, 1800 and 1700 proofs respectively. The emission of hydrocarbon from engine at full load (100 % load) when it developed its rated power (2.24 kW) was found to be 3.54, 1.97, 0.28, 0.09 and 1.86 % on kerosene and denatured ethanol of 2000, 1900, 1800 and 1700 proof respectively. It has been observed that the emission of hydrocarbon from the GK300 engine on kerosene ranged between 1.76 to 3.29 % under different loading condition. The hydrocarbon emission from the engine was observed in the range of 0.61 to 1.46, 0.24 to 0.69, 0.16 to 0.29 and 0.31 to 0.80 % on denatured ethanol of 2000, 1900, 1800 and 1700 proofs respectively. The emission of hydrocarbon from engine at full load (100 % load) when it developed its rated power (2.94 kW) was found to be 2.82, 0.64, 0.25, 0.18 and 0.79 % on kerosene and denatured ethanol of 2000, 1900, 1800 and 1700 proof respectively.

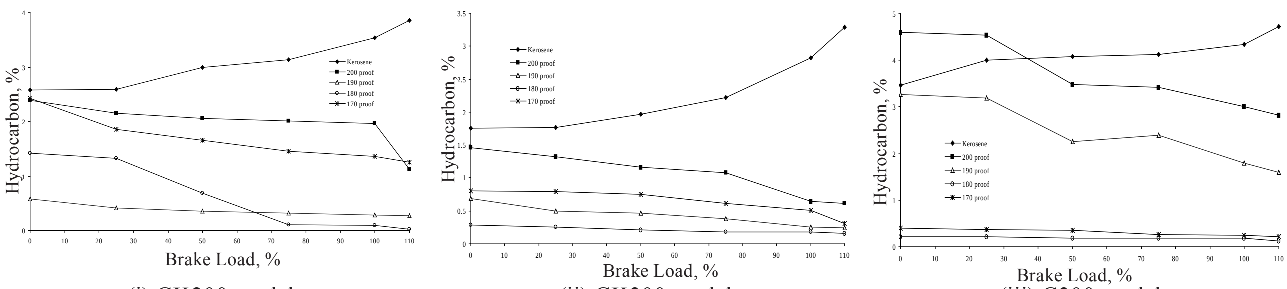
It has been observed that the emission of hydrocarbon from the G300 engine on kerosene ranged between 3.47 to 4.72 % under different loading condition. The hydrocarbon emission from the engine was observed in the range of 2.82 to 4.6, 1.6 to 3.26, 0.13 to 0.22 and 0.21 to 0.40 % on denatured ethanol of 2000, 1900, 1800 and 1700 proofs respectively. The emission of hydrocarbon from engine at full load (100 % load) when it developed its rated power (3.73 kW) was found to be 4.34, 3.0, 1.79, 0.18 and 0.37 % on kerosene and denatured ethanol of 2000, 1900, 1800 and 1700 proof respectively.

The above results indicate that emission of hydrocarbon from the engine was considerably less on denatured ethanol of 2000, 1900, 1800 and 1700 proof as compared to that observed on kerosene. It was also observed that the emission of hydrocarbon decreases with increase in water content in ethanol till it contained 9% water and it than increased when the water content was 13.5 % (denatured 1700 proof ethanol). However, the lowest emission of hydrocarbon was observed on denatured ethanol of 1800 proof. The reduction in emission of hydrocarbon on denatured ethanol was due to leaning effect of ethanol and the above findings are in line with that of Ferfecki and Sorenson (1983) and Chandan Kumar (2002).

Emission of Nitric Oxide

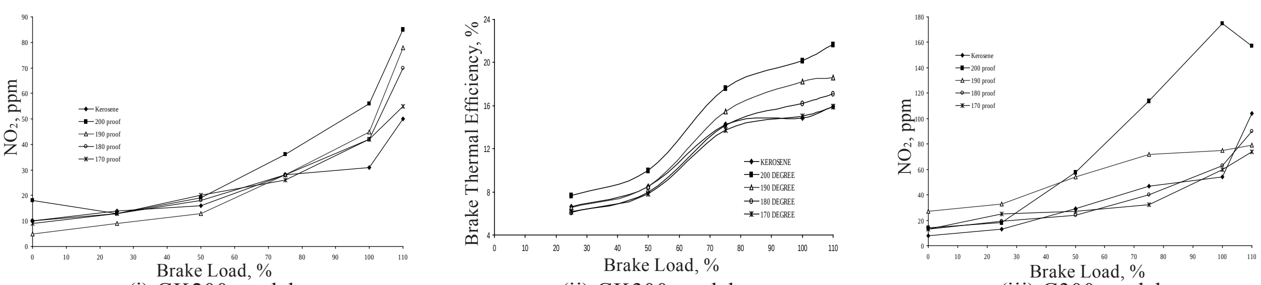
The change in emission of nitric oxide from different engines on kerosene and denatured ethanol

Fig. 6 Hydrocarbon content in exhaust emission from different engines on different fuels



(i) GK200 model (ii) GK300 model (iii) G300 model

Fig. 7 Nitric oxide in exhaust emission from different engines on different fuels



(i) GK200 model (ii) GK300 model (iii) G300 model

of different proof at various loads is shown in **Fig. 7**. It has been observed that the emission of nitric oxide from the GK200 engine on kerosene ranged between 10 to 50 ppm under different loading condition. The nitric oxide emission from the engine was observed in the range of 18 to 85, 5 to 78, 10 to 70 and 9 to 55 ppm on denatured ethanol of 2000, 1900, 1800 and 1700 proofs respectively. The emission of nitric oxide from engine at full load (100 % load) when it developed its rated power (2.24 kW) was found to be 31, 56, 45, 42 and 42 ppm on kerosene and denatured ethanol of 2000, 1900, 1800 and 1700 proof respectively.

It has been observed that the emission of nitric oxide from the GK300 engine on kerosene ranged between 17 to 50 ppm under different loading condition. The nitric oxide emission from the engine was observed in the range of 7 to 239, 8 to 206, 8 to 142 and 5 to 125 ppm on denatured ethanol of 2000, 1900, 1800 and 1700 proofs respectively. The emission of nitric oxide from engine at full load (100 % load) when it developed its rated power (2.94 kW) was found to be 30, 170, 150, 102 and 98 ppm on kerosene and denatured ethanol of 2000, 1900, 1800 and 1700 proof respectively.

It has been observed that the emission of nitric oxide from the G300 engine on kerosene ranged between 27 to 79 ppm under different loading condition. The nitric oxide emission from the engine was observed in the range of 14 to 157, 27 to 79, 13 to 90 and 13 to 74 ppm on denatured ethanol of 2000, 1900, 1800 and 1700 proofs respectively. The emission of nitric oxide from engine at full load (100 % load) when it developed its rated power (3.73 kW) was found to be 75, 175, 75, 63 and 60 ppm on kerosene and denatured ethanol of 2000, 1900, 1800 and 1700 proof respectively.

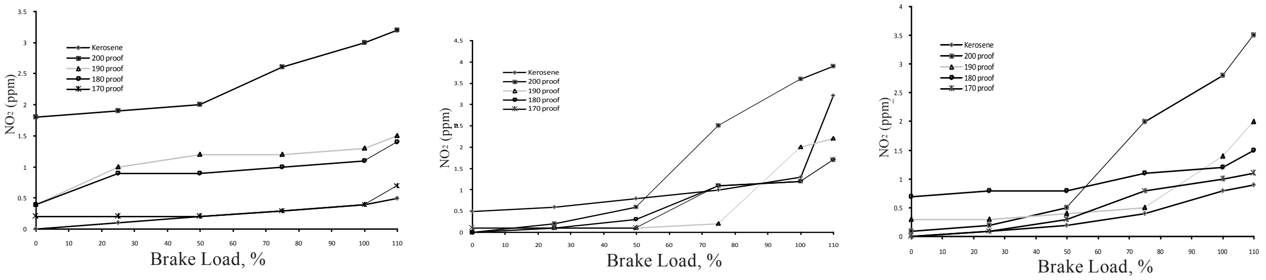
The above observations reveal that an increase in water content in denatured ethanol proofs resulted reduction in nitric oxide emission from engines, which is in line with the finding of Beyeriein *et al.* (2001) and Chandan Kumar (2002). Further, exhaust emission from engines indicate higher emission of nitric oxide when operating on denatured anhydrous ethanol compared to kerosene. This observation is also in line with the finding of Ferfecki and Sorenson (1983) which shows about 116 % increase in emission of nitric oxide when gasoline-ethanol blend containing 25 % anhydrous ethanol was used in an engine set to run on air-fuel ratio for maximum power and without modification of engine carburetor. The above findings of higher emission of nitric oxide in case of ethanol could be attributed to the facts that the peak cylinder pressure and temperature when operating on ethanol is higher which results in formation of more NOx. Any presence of water in alcohol depresses the rise in temperature thus the formation of NOx has been observed less with aqueous ethanol than the anhydrous ethanol.

Emission of Nitrogen Dioxide

The change in emission of nitrogen dioxide from GK200 model engine on kerosene and denatured ethanol of different proof at various loads is shown in **Fig. 8**. It has been observed that the emission of nitric oxide from the engine on kerosene ranged between 0.0 to 0.5 ppm under different loading condition. The nitrogen dioxide emission from the engine was observed in the range of 1.8 to 3.2, 0.4 to 1.5, 0.4 to 1.4 and 0.2 to 0.7 ppm on denatured ethanol of 2000, 1900, 1800 and 1700 proofs respectively. The emission of nitrogen dioxide from engine at full load (100 % load) when it developed its rated power (2.24 kW) was found to be 0.4, 3.0, 1.3, 1.1 and 0.4 ppm on kerosene and denatured ethanol of 2000, 1900, 1800 and 1700 proof respectively.

The change in emission of nitrogen dioxide from GK300 model engine on kerosene and denatured ethanol of different proof at various loads is shown in **Fig. 8**. It has been observed that the emission of nitrogen dioxide from the engine on kerosene ranged between 0.5 to 3.2 ppm under different loading condition. The nitrogen dioxide emission from the engine was observed in the range of 0.0 to 3.9, 0.0 to 2.2, 0.0 to 1.7 and 0.1 to 1.7 ppm on denatured ethanol of 2000, 1900, 1800 and 1700 proofs respectively. The emission of nitrogen dioxide from engine at full load (100 % load) when it developed its rated power (2.94 kW) was found to be 1.3, 3.6, 2.0, 1.2 and 1.2 ppm on kerosene and denatured

Fig. 8 Nitrogen di oxide in exhaust emission from different engines on different fuels



(i) GK200 model (ii) GK300 model (iii) G300 model

ethanol of 2000, 1900, 1800 and 1700 proof respectively.

The change in emission of nitrogen dioxide from G300 model engine on kerosene and denatured ethanol of different proof at various loads is shown in **Fig. 8**. It has been observed that the emission of nitrogen dioxide from the engine on kerosene ranged between 0.0 to 0.9 ppm under different loading condition. The nitrogen dioxide emission from the engine was observed in the range of 0.1 to 3.5, 0.3 to 2.0, 0.7 to 1.5 and 0.0 to 1.1 ppm on denatured ethanol of 2000, 1900, 1800 and 1700 proofs respectively. The emission of nitrogen dioxide from engine at full load (100 % load) when it developed its rated power (3.73 kW) was found to be 0.8, 2.8, 1.4, 1.2 and 1.0 ppm on kerosene and denatured ethanol of 2000, 1900, 1800 and 1700 proof respectively.

The above results indicate that emission of nitrogen dioxide in comparison to nitric oxide is negligible. In fact NOx emission from an engine exhaust has primarily a large proportion of nitric oxide them the nitrogen dioxide and the same has been observed in the experiments also.

Conclusions

On the basis of the results obtained the following conclusions were drawn:

1. The brake horsepower of the engines was found to increase with increase in the brake load under all fuel types. Further all engines developed its rated power at full load on all fuels at rated engine rpm.

2. The fuel consumption of the engines was found to vary on different fuel types and it was found to increase with increase in brake load. Further the fuel consumption of the different model engines was when developing its rated power had 4.5-12.7, 15.9-22.1, 22.7-39.9 and 40.9-65.8 % higher consumption of 2000, 1900, 1800 and 1700 proof denatured ethanol respectively in comparison to kerosene.

3. The brake specific fuel consumption of the engine was found to be highest at 25 % load when operating on denatured ethanol of 1700 proof and lowest at 110 % load when operating on kerosene for each engine.

4. The bsfc of the GK200, GK300 and G300 model engine at full load when developing its rated power was found to be 572.3, 598.4, 702.6, 762.4, and 857.3 g/kW^{-h}; 519.9, 540.8, 625.0, 746.8, 90.9 g/kW^{-h}; and 465.1, 519.8, 545.2, 588.2 and 680.0 g/kW^{-h} on kerosene, denatured ethanol of 2000, 1900, 1800 and 1700 proof respectively.

5. The comparison of bsfc indicates that it was lowest for all loads for the G300 model engine having the higher compression ratio (6.5: 1).

6. The brake thermal efficiency of the engine was found to be higher on denatured ethanol proofs (highest for 2000 proof) as compared to kerosene on all the brake load conditions. Further, the brake thermal efficiency on selected fuels was observed higher at all loads for G300 model engine having highest compression ratio of 6.5: 1. This indicates that even higher compression ratio engines could perform better on ethanol fuel.

7. The emission of hydrocarbon was found more on kerosene. The emission of hydrocarbon from GK200, GK300 and G300 model engine at full load when the engine developed its rated power was found to be 3.54 and 0.09 to 1.97; 2.82 and 0.18 to 0.79; and 4.34, 0.18 to 3.0 % on kerosene and different denatured ethanol proofs respectively.

8. The emission of NOx from GK200, GK300 and G300 model engine at full load when the engine developed its rated power was found to be 31.4 and 42.4 to 59.0; 31.3 and 99.2 to 173.6; and 75.8 and 61.0 to 177.8 % on kerosene and different denatured ethanol proofs respectively.

On the basis of above findings, it can be said that ethanol of 2000, 1900, 1800 and 1700 proof may be used to replace kerosene as fuel in the petrol start kerosene run type small spark ignition engines. The selected ethanol proofs are stable and they have similar power producing capabilities as kerosene. The engine having higher compression ratio was found to have lesser brake specific fuel consumption and higher brake thermal efficiency. However, the use of 1800 proof ethanol suitably denatured with kerosene may be recommended as replacement fuel for the engine based on observed engine performance.

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Reducing Draft Required for a Simple Chisel Tool

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Abstract

The objective of this study was to reduce the energy requirements of the soil preparation process by adding coulters at different positions to the chisel tillage tool by studying the following points:

a. The effect of adding coulters to a standard tillage tool –includinga laboratory simulation of a chisel plow tillage tool– on the draft acting on the tillage tool compared to the draft acting on the same tool without coulters.
b. The draft acting on the total combined machine –which consists of the tillage tool and the coulter– versus the draft acting on the previously mentioned tillage tool alone.
c. Simulating an imaginary combined machine consisting of the conventional chisel plow with coulters added to its frame.

Results showed that the draft affecting the tool was reduced by (18 %) at a plowing depth of 12 cm and coulter depth equal to 83.33 % of the plowing depth while the coulter was positioned 10 cm in front of the tool.

Offset distance of 12 cm between coulters and plowing tool on both sides of the tool resulted in a 10.61 % decrease in the draft affecting the tool.

The study also concluded that theoretically if the weight of every added coulter was less than 4.78 kg, overall draft of the combined machine may be decreased.

Introduction

The economic conditions and environmental considerations are becoming the most effective drivers of any discussions about productivity versus power consumption when it comes to tillage power, considering that primary tillage consumes about two-thirds of the horsepower used for all production and harvesting operations and comprises about 20 percent of all machine costs (Carter and Colwick, 1971).

On the other hand, the chisel plow is widely used for preparing the soil for different corps in almost all Egyptian farms because of its ease of use especially when compared to the Moldboard and Disk plows which require special adjustments, higher power and operating cost in order to operate safely and properly.

Also it is a preferred choice of the Egyptian farmers because it is easily manufactured locally which makes it affordable and consequently cost effective.

Most of chisel plows used in Egypt are locally manufactured with throats less than 60 cm, which is in-proper in weedy lands and that having large amounts of residues. This causes the plow to float and consequently it doesn't provide the required depth of cut.

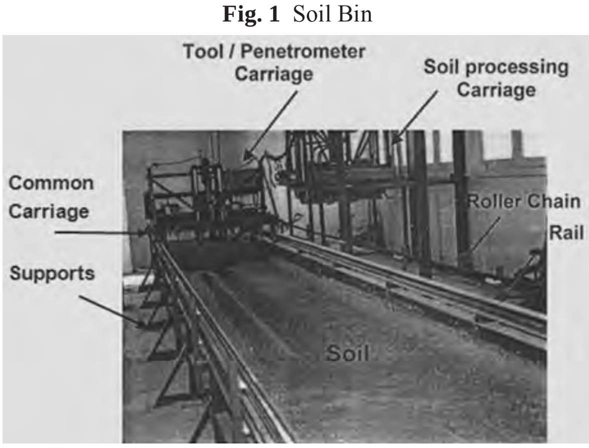
Moreover, most of the chisel plows –locally manufactured– might be subjected to tines and shank distortion when used in heavy soils.

Adding coulters to the chisel plow in different positions might result in decreasing the draft force, overall energy requirements, and consequently increasing the plowing quality.

Materials

Experiments conducted can be classified according to the results relevance into primary and secondary, the primary experiments are the experiments that derived the results related directly to the main topic and they are mainly the Soil Bin experiments, while the secondary experiments are the experiments executed to measure indicators and variables affecting the primary experiments results indirectly like for example the direct shear, bulk density, and penetration resistance tests

Fig. 1 Soil Bin



related to the used soil.

Soil Bin

As shown in (**Fig. 1**), the laboratory tillage tests were conducted using a fully automated computer controlled soil bin facility for soil dynamics research at the department of Agricultural Engineering, Faculty of Agriculture, Alexandria University.

This facility features the state of the art technology with respect to the instrumentation, control and automation.

Shear Box

The direct shear box apparatus of the Model (D-110 Ay, USA), was used for measuring soil shear strength parameters. The box consists of upper and lower half. The cross section area of the box is 25 cm^2.

Universal Hitching Unit

To add the capabilities of positioning coulters in different positions relative to the tillage tool of the Soil Bin, a specially designed universal hitching frame was manufactured and mounted on the Soil Bin to provide the coulters the ability to be positioned in front of and on both sides of the tillage tool.

The standard soil bin narrow blade was used as a tillage tool instead of the real commercial chisel plow. Besides that, this frame was needed to provide the hitched tillage unit –the coulter– the ability to be combined with the main tillage tool of the soil bin to provide the capability of studying any unit effect on the draft affecting the experimented tillage tool (**Fig. 2**).

The Coulter

The 5 cm × 2 cm coulter shank was fixed to a saw-toothed coulter of 25 cm diameter using a special made axle having a sleeve bearing to be as shown in **Fig. 3**.

Methods

Experimental Design was developed using dimensional analysis and similitude methods.

Variables studied in this research are listed in **Table 1**. Dimensional analysis and similitude methods were used in the experimental design and calculations needed to reach the empirical prediction equation easy to be used in the development of the prototype essential to transform the results into a practical application in the future.

where

M is Implement total mass.

S is Plowing speed.

R is Coulter depth.

R' is presenting the Perpendicular distance between coulter surface and the plowing tool bottom in front of the tool.

R'' is presenting the Perpendicular distance between coulter center

Table 1 Variables will be considered in the experiment

Variable	Dimension F	Dimension M	Units
M	$FL^{-1}T^2$	M	kg
S	LT^{-1}	LT^{-1}	cm/sec
R	L	L	cm
R'	L	L	cm
R″	L	L	cm
d	L	L	cm
F_D	F	MLT^{-2}	kg.cm/sec^2
a	L^2	L^2	cm^2

Fig. 3 Final assembly of the coulter used in the experiment

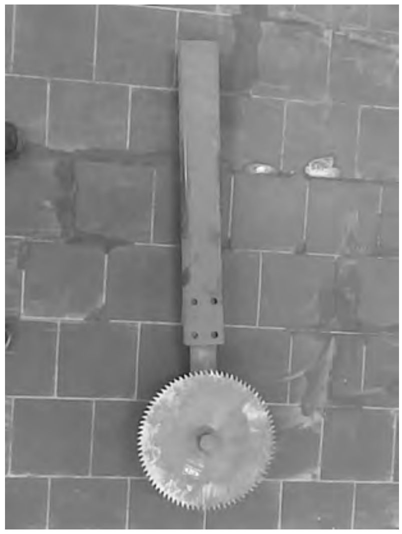
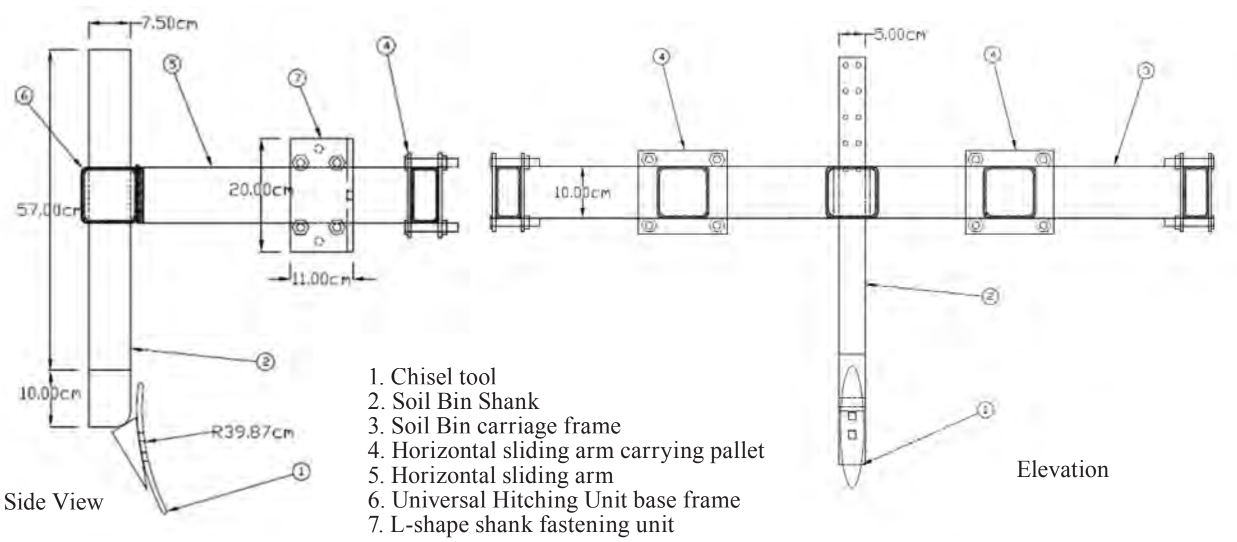


Fig. 2 Universal Hitching Unit designed for the experiment



and the plow tool bottom on both sides of the tool (Offset).

d is Plowing depth.

F_D is Draft (Horizontal component).

a is Disk (coulter) area interacting with soil.

PI groups developed according to Buckingham (PI) theorem and five PI groups reached were as following:

$\pi_1 = R'' / R'$, $\pi_2 = R / R'$, $\pi_3 = d / R'$, $\pi_4 = a / R'^2$, $\pi_5 = F_D R' / MS^2$

Based on the PI groups reached and independency check applied to them, three sets of experiments were concluded and each set was designed to be fully executed in one day, results of each set depended on changing one variable in the PI group examined by the set while all other variables in the same PI group and all other groups were considered as constants.

Fig. 4 Positioning coulter infront of the plowing tool for the first and second set of experiments

The first set of experiments was executed by changing the plowing depth, while the second set was executed by changing coulter depth which resulted in changing also the disk (coulter) area interacting with soil, the third set was executed by changing the offset distance.

Experiments procedures

Experiments were executed on two phases which are the soil processing and preparation phase, and tillage experiments phase respectively. Prior to each tillage set of experiments, the soil was processed and prepared according to the following steps:

- Checking the system and removing the plastic sheet –used to limit the losses in soil moisture content during experiments days– off the soil surface.
- Implement preparation carriage for soil system preparation.
- Adjusting the carriage forward speed.
- Plowing the soil using the rotary plow with water sprinkling.
- Plowing the soil using the rotary plow with leveling.
- Changing the carriage.
- Experiment set execution.

Soil properties measurements

The soil used was brought from Al-Hammam farm, Alexandria University. The mechanical analysis of the soil was carried out at the Soil and Water Dept., Alexandria University.

This soil is classified as a sandy loam soil as the mechanical analysis showed that it consists of 71 % sand, 13 % silt, and 16 % clay.

Although the effect of the soil properties on tillage process is not what is discussed in this research but it was very important to be aware of soil properties for deeper understanding of the results, therefore; soil shear strength, bulk density, moisture content, and penetration resistance, were measured at the beginning of each experimental scheduled day just before starting the experiments to have an accurate record of these properties.

Results and Discussion

Dimensional and reduced matrices were developed using all dimensions of the variables will be considered in the experiment, After calculating the dimensional and reduced matrices and accordingly, PI groups shown previously.

According to Buckingham PI theorem, this system can be described by the following equation:

Fig. 5 Tool draft difference % –Set 1

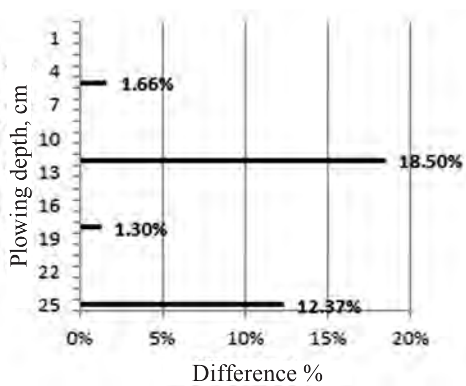
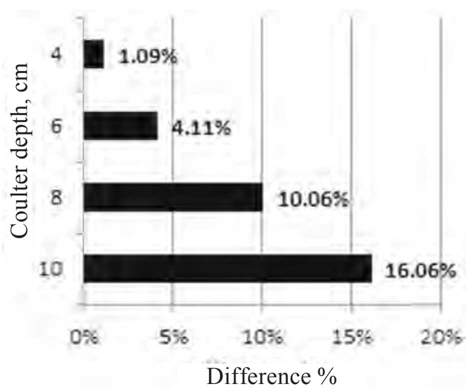


Fig. 6 Tool draft difference % –Set 2



$$(F_D R' / MS^2) = C \times (R'' / R')^{c1} \times (R / R')^{c2} \times (d / R')^{c3} \times (a / R'^2)^{c4} \;..... (1)$$

where

C is constant.

C_x is slope of the trend line presenting the logarithmic relation between each PI group in the right side of **Eqn. 1** and the main PI group on the left side of the equation. This slope is called the coefficient of the PI group.

Experiments

Before starting the execution of the experimental sets, drafts resulted from both the coulter alone, the chisel tool alone without the coulter were measured at the experimented depths considered in each set.

Results obtained from all sets showed also that although the draft affecting the plowing tool was decreased by the addition of the coulter/s, the overall draft of the combined machine was increased by adding the draft of the coulter/s alone –which was more than 20N in all sets– to the tool draft.

First set (plowing depth)

In this set shown in **Fig. 4**, the plowing depth was changed while coulter depth, plowing speed, and perpendicular distance between coulter and plowing tool to the front of the tool remained constant.

As shown in **Fig. 5,** when relating coulter 10 cm depth to the plowing depth, we found that the maximum decrease of the draft affecting the tool was 18.5 % and it was reached at plowing depth of 12 cm which is 83.33 % of the plowing depth. This depth is almost the same depth where measured and predicted soil mechanical resistance met in experiments of (Adamchuk and Skotnikov, 2003), and this explains why the maximum effect was at this depth.

Second Set (Coulter Depth)

In this set also shown also in **Fig. 4**, as the coulter remains infront of the plowing tool, coulter depth was changed while plowing depth, plowing speed, and perpendicular distance between coulter and plowing tool to the front of the tool remained constant.

As shown in **Fig. 6**, Considering the coulter depth related to the plowing depth which was 15 cm in this set of experiments, we found that the maximum decrease of the draft affecting the tool was 16.06 % and it was reached at coulter depth of 10 cm which is 66.67 % of the plowing depth.

In both the first and second sets of experiments, weight of the coulter alone was 19.75 kg while the weight of the chisel plow alone was 12.5 kg.

Third Set (Offset Distance)

In this set shown in **Fig. 7** two coulters were located on both sides of the chisel tool. Offset distance between coulter center and the plow tool bottom was changed while coulter depth, plowing depth, plowing speed and perpendicular distance between coulter and plowing tool to the front of the tool were kept constant.

As shown in **Fig. 8**, Considering the coulter depth related to the plowing depth which was 15 cm in this set of experiments, we found that the maximum decrease of the draft affecting the tool was 10.61 % and it was reached at coulter offset

Fig. 7 Positioning coulter infront of the plowing tool for the first and second set of experiments

Fig. 8 Tool draft difference % –Set 3

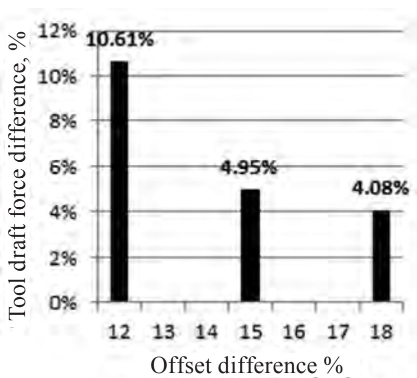
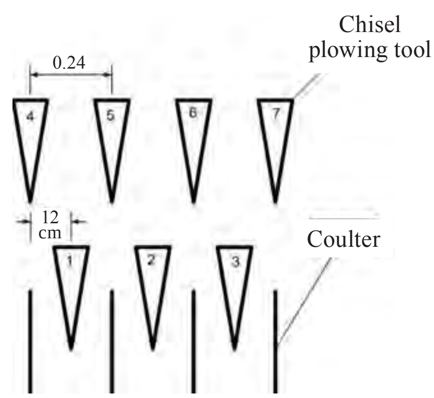


Fig. 9 Imaginary combined machine



distance of 10 cm which is 80 % of the plowing depth. Also we can conclude also that difference between drafts caused by increasing the offset distance more than 12 cm are insignificant.

Imaginary Combined Machine

Results reached from the experiments were applied on an imaginary combined machine **Fig. 9** consisting of 7 chisel plowing tools, 4 coulters, working in the same soil at plowing depth of 15 cm, coulter depth of 10 cm, offset distance of 12 cm and forward speed of 0.084 m/sec, overall combined machine weight of 166.5 kg as the single coulter weight is 19.75 kg and the single plowing tool weight is 12.5 kg, and the weight of 7 shanks chisel plow without coulters is 87.5 Kg.

Taking in consideration the effect of soil properties on drafts within the limited working conditions we had in our experiments, we concluded that draft affecting the combined machine is 280.385 N which is 56.06 % more than the 179.656 N we calculated for a regular 7 shanks chisel plow working in the same conditions.

This required us to try to find out the most reasonable reason and if there is any further recommendation to enhance this result.

Development of the Prediction Equation:

Experiments where finished and the measured drafts were plotted against the variable experimented in each set using a technical computing software (MATLAB Version 7.0.1.24704 (R14) Service Pack 1). Using the method of least squares through the same software, a trend line was drawn and from the equation of that trend line, the exponent Cx was found for each PI group, correlation coefficient was applied to insure that the strength of the linier relation between variables is acceptable.

By substituting the values of Cx in **Eqn. 1** it will become as following:

$$(F_D R' / MS^2) = C \times (R'' / R')^{0.051} \times (R / R')^{0.14} \times (d / R')^{0.45} \times (a / R'^2)^{0.1} \quad (2)$$

By substituting the different values of the PI groups calculated from the sets of experiments which were applied according the dimensional analysis experimental design, we will get different values of Cs as following:

Experimental Set 1:

$15.93 = C \times 1^{0.14} \times 0.5^{0.45} \times 3.66^{0.1}$
$C = 19.11$
$19.00 = C \times 1^{0.14} \times 1.2^{0.45} \times 3.66^{0.1}$
$C = 15.37$
$25.87 = C \times 1^{0.14} \times 1.8^{0.45} \times 3.66^{0.1}$
$C = 17.44$
$34.07 = C \times 1^{0.14} \times 2.5^{0.45} \times 3.66^{0.1}$
$C = 19.81$

Experimental Set 2:

$18.39 = C \times 0.4^{0.14} \times 1.5^{0.45} \times 1.01^{0.1}$
$C = 17.40$
$19.09 = C \times 0.6^{0.14} \times 1.5^{0.45} \times 1.81^{0.1}$
$C = 16.10$
$19.61 = C \times 0.8^{0.14} \times 1.5^{0.45} \times 2.7^{0.1}$
$C = 15.26$
$20.68 = C \times 0.4^{0.14} \times 1.5^{0.45} \times 1.01^{0.1}$
$C = 15.13$

Experimental Set 3:

$24.86 = C \times 1.2^{0.051} \times 1^{0.14} \times 1.5^{0.45} \times 7.33^{0.1}$
$C = 16.82$
$25.31 = C \times 1.5^{0.051} \times 1^{0.14} \times 1.5^{0.45} \times 7.33^{0.1}$
$C = 16.93$
$25.38 = C \times 1.8^{0.051} \times 1^{0.14} \times 1.5^{0.45} \times 7.33^{0.1}$
$C = 16.82$

By calculating the average value of the Cs, we reach the value of the constant C which is 16.93.

By substituting the values in **Eqn. 2**, we reach the prediction equation as following:

$$F_D = 16.93 \times (MS^2 / R') \times (R'' / R')^{0.051} \times (R / R')^{0.14} \times (d / R')^{0.45} \times (a / R'^2)^{0.1} \quad (3)$$

Eqn. 3 shows that any increase in the mass of the overall combined machine increases the draft, and when we compare the weight of the imaginary combined machine presented in the previous section to the weight of the 7 shanks chisel plow presented in the same section, we can find that the former is almost the double.

By calculating the draft affecting the imaginary combined machine using **Eqn. 3**, we found that the draft is 312.18 N with an increase of 11.3 % than the calculated before.

$$F_D = 16.93 \times [\{166.5 \times (0.084)^2\} / 0.1] \times (0.12 / 0.1)^{0.051} \times (0.1 / 0.1)^{0.14} \times (0.15 / 0.1)^{0.45} \times (0.147 / 0.12)^{0.1}$$

$$F_D = 16.93 \times 11.748 \times 1 \times 1 \times 1.2 \times 1.308 = 312.18 \ N$$

Considering that difference between the value calculated by the equation and the value calculated according to the assumptions of the imaginary combined machine, we can conclude that decreasing the overall weight of the implement will result in decreasing the overall draft and the recommended overall implement weight could be calculated by substituting the draft in **Eqn. 3** as 179.656 N which is the regular 7 shanks chisel plow and then we find the desired weight as following:

$$F_D = 16.93 \times [\{M \times (0.084)^2\} / 0.1] \times 1 \times 1 \times 1.2 \times 1.308 = 179.656 + (179.656 \times 0.113) = 199.957 \ N$$

$$\{M \times (0.084)^2\} / 0.1 = 7.525$$

$$M = 106.647 \ kg$$

Weight of the 7 shanks chisel plow without coulters = 87.5 kg

Weight of the additional four coulters = 106.647 − 87.5 = 19.147 kg

Summary and Conclusion

In an attempt to reduce the energy requirements of the soil preparation process, this study was conducted addressing the conventional chisel plow widely used in the Egyptian farms. The study was carried out using a soil bin under controlled conditions which facilitate measuring draft, soil moisture content, penetration resistance, and all other needed variables. Moreover, dimensional analysis and similitude methods were used in the experimental design and also helped understanding the results obtained.

The main idea was about adding coulters at different positions to the chisel tillage tool and studying the effect on the draft affecting the tool.

Results obtained showed that the draft affecting the tool was reduced by (18 %) at a plowing depth of 12 cm and coulter depth equal to 83.33 % of the plowing depth while the coulter was positioned 10 cm infront of the plowing tool.

On the other hand, the offset distance of 12 cm between coulters and plowing tool on both sides of the tool resulted in a 10.61 % decrease in the draft affecting the tool.

The study concluded practically that adding coulters resulted in a convenient decrease in the draft affecting the tillage tool and also concluded theoretically that if the weight of every added coulter was less than 4.78 kg, overall draft of the combined machine consisting of the chisel plow and the additional coulters might be decreased significantly.

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■■

Manufacture Evolution of a Microbial Contamination Detection Unit for Processed Tomatoes inside Food Factories

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Abstract

Extremely needed of foodborne toxins in-situ monitoring, in the Egyptian food processing plants, is due to frequent food poisoning cases. The new method was developed in real time program. Near infrared data were acquired with fresh and spoiled tomato juices. The spectral data were studied using discriminant analysis. A test set of two groups of tomato juices (fresh and spoiled) were used for testing the developed model. Fresh and spoiled juices were classified with an accuracy of 75 and 80 %, respectively. Manufactured firmness tester was used to categorize the tomatoes in groups for this experiment before juice extraction.

Introduction

Severe impacts on human health exist if no appropriate monitoring program for toxins in food is in place. Foodborne diseases are a widespread and growing public health problem, both in developed and developing countries. In industrialized countries, the percentage of the population suffering from foodborne diseases each year has been reported (WHO, 2007) to be up to 30 %. The increase in the number of pollutants found in soil, water sources and food, due to the large use of chemicals, poses potential hazard to human health. As a result more stringent legislation has been introduced to monitor and control the release of contaminants. Also, the demand for fresh natural foods, ready prepared, and for cook-chill food containing less preservatives and additives, more nutritional value and free from pathogenic microorganisms, has fuelled demands for rapid sensing methods. Conventional ‘off-site’ analysis requires the samples to be sent to a laboratory for testing. These methods allow the highest accuracy of quantification and the lowest detection limits, but are expensive, time consuming and require the use of highly trained personnel. There are now many assays on the market, which promise results within 24 h. Tomato is known as one of the most important agricultural products in the world and one of the richest sources of carotenoids including lycopene. Lycopene may reduce the risk of developing diseases such as cancer and cardiovascular diseases (Gann *et al*., 1999; Sesso *et al*., 2003 and Sesso *et al*., 2005). Egypt is considered to be the fifth largest tomato producing country in the world 8,544,990 ton (FAO, 2010). Some of microorganisms can be treated by either heat or pressure but others not such as Bacillus coagulans which is one of the most frequently isolated microorganisms from spoiled canned tomato juice and acidified vegetable products. Spores of B. coagulans are pressure-resistant and relatively heat-resistant at acidic pH and are able to germinate and grow at pH values between 3.7 and 4.5 (Mallidis *et al*., 1990; Palop *et al*., 1999). Fruit softness is used as an indicator of quality but no numerical or quantifiable measurements are included in the standards; inspectors grade for firmness as the fruit “yields readily to slight pressure” (USDA, 1991). It is difficult to accurately grade the tomatoes based on firmness. There are many different methods and devices reported to accurately and objectively measure firmness. Such devices can be either destructive or nondestructive and are often based on compression, shearing, or cutting forces (Ritenour *et al*., 2002). The ideal method for detecting infections should require minimum sample preparation and be quick, precise and inexpensive (Goodacre & Kell, 1996). A method for reducing sampling time would be to use near infrared (NIR) spectroscopy for microorganism detection (Lanza & Li, 1984). Transmission or reflection techniques can be used in infrared (IR) spectroscopy for quantitative measurement.

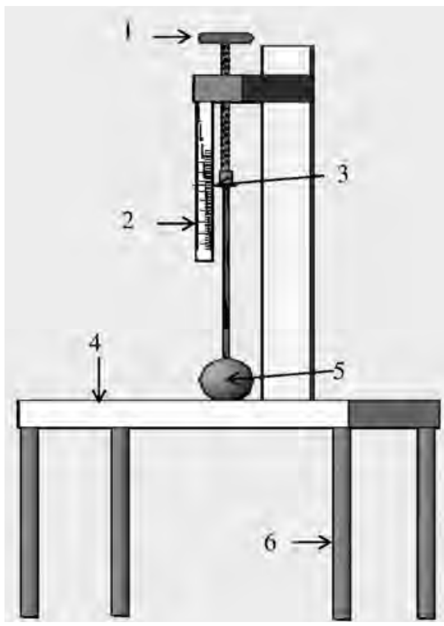
Transmission is characterized by light entering a sample, traveling through the sample, and exiting through the side opposite the entry. Opposite to transmission, in reflection, the light exits at the same side as its entry. There are three types of reflection, including specular, diffuse and internal reflection. While specular reflection is mirror-like reflection occurring at a smooth surface, diffuse reflection occurs from light penetrating just below a rough surface. Instruments are designed to measure only diffusely reflected light because it contains useful information about the sample (Ingle & Crouch 1988 and Wehling, 1998). Ruan *et al.* (1998) estimated Fusarium scab damage on wheat using a vision system which was found to be more accurate than a human panel, while Dowell *et al.* (1998) identified scab-damaged kernels properly using NIR. Aneshansley *et al.* (1997) studying Venturia inaequalis infection on apple tissue, noted a reflectance reduction in the 600-930nm waveband. Brown rot damaged tissue caused by the fungus Monilinia fructicola reduced reflectance at the 700-800 nm wavebands. Hahn (2002) detected F. oxysporum on tomatoes using spectral Fourier signatures, with an accuracy of 91.31 %. Hahn *et al.* (2004) used NIR for Rhizopus Stolonifer conidia detection, the conidia was detected with accuracy of 78 %.

Fourier transform infrared (FT-IR) spectrometry-based approach was developed by Yu *et al.* (2004) for microbial differentiation and quantification of eight different microorganisms including Salmonella. FT-IR spectroscopy combined with chemometrics was able to differentiate the microorganisms studied at low concentration level of 103 colony-forming units (CFU)/ml in apple juice. Another report demonstrated the use of FT-IR spectrometry to differentiate E. coli O157: H7 from other bacteria inoculated into apple juice (109 CFU/ml) (Al-Holy *et al.*, 2006). Lin *et al.* (2004) used FT-IR spectrometry to differentiate between intact and injured Listeria and to distinguish this strain from other selected Listeria strains. Buratti *et al.* (2011) used near and mid infrared for effective fermentation monitoring in wine industry; Principal Component Analysis was applied to spectral data, as an exploratory tool, to uncover molecular modifications during the fermentation process. NIR spectral data usually analyzed by Partial Least Square regression (PLS) which is a very useful statistical technique when there are a lot of highly correlated prediction variables (multicollinearity). PLS regression tries to extract the limited numbers of latent factors (which are linear combinations of the original prediction variables) that explain as much as possible the covariance between the prediction and response variables. It is a very common technique in the treatment of spectral data (Todorov *et al.*, 1994 and Liu *et al.*, 2003) where the number of prediction variables is greater than the number of observations. Variable selection is one of the important practical issues for many scientific engineers. PLS (Partial Least Squares) regression combined with the Variable Importance Projection (VIP) scores is often used when the multicollinearity. VIP provides a score for each variable such that it is possible to rank the variables according to their predictive power in the PLS model (the higher the score the more importance a feature presents). This study aims to facilitate tomato juice quality monitoring and discriminate the adequate juice for the subsequent processes in plants, using optical reflectance. Rotten tomatoes were selected for this study as a problem or when fruits are allowed to fully ripen on the plant. These conditions can be due to fruit rotting on the machinery or due to lack of workers hygiene practice. The spectral signatures were analyzed by Discriminant Analysis which provided algorithms capable of predicting whether the tomato juice is fresh or spoiled.

Materials and Methods

Two hundred red tomatoes were collected from markets and carefully washed with clean water to remove as many conidia as possible. Spoiled tomatoes obtained from rotten tomatoes that added to sterilized distilled water and mixed. Tomato fruits were immersed in a tube of 20 liters of contaminated water for 6 hours. Once spoiled tomatoes ob-

Fig. 1 Manufactured tomato fruits firmness tester



1: weight of 9.8N, 2: graded bar in millimeters, 3: movable indicator, 4: table, 5: tomato fruit, 6: tester legs tained, the firmness device was used to classify the tomatoes according to its firmness. For this experiment, one firmness tester was constructed using a 15 mm diameter probe and a 9.8N force (**Fig. 1**).

Once tomatoes categorized in groups based on its firmness; entered separately the juice extraction unit flowed to the developed detection unit that is named High Critical Control Point (HCCP) by quality monitoring control unit (**Fig. 2**).

This control point consists of an Ocean Optic USB 2000+ (Ocean Optics, HALMA group company) computerized spectrophotometer to acquire spectral reflectance signatures in the 500-1000 nm range with a resolution of 10 nm. Tomato juice measurements were obtained by a bifurcated optical fiber, which carried the illuminating radiation towards the tomato juice and the reflectance back to the built in monochromator (inside the ocean optics USB 2000). The tomato juice reflectance measured at a height of 1cm avoiding direct contact with the juice (**Fig. 3**).

The maximum signature reference was obtained by irradiating the Spectralon material with the spectrophotometer halogen light source, while the minimum or dark signature reference was obtained with the spectrophotometer light source off. Spectralon diffuse reflectance material (Labsphere, Inc) was used as spectral reference due to its high reflectivity (98-99 %) in the 250-2500 nm range. Both references were acquired at the beginning of the experiment. The spectrophotometer acquired the spectral reflectance signature once the tomato juice entered the cone. Dividing the difference between the tomato juice reflectance signature (R_t) and the dark reference spectrum (R_d) by the difference between the Spectralon (R_s) and dark reference spectrum (R_d) provides the relative reflectance ratio. This relative reflectance ratio characterizes a freshness or spoilages spectral signature (FJSS or SJSS) given by **Eqn. 1**.

$$FJSS \text{ or } SJSS - [(R_t - R_d) / (R_s - R_d)] \quad (1)$$

The relative reflectance ratio for FJSS and SJSS were obtained from each category scale and the spectral difference between both signatures provided a value proportional to the freshness and spoilages. The spectral differences were analyzed by Discriminant Analysis using XLSTAT 2013 to determine the best wavelengths to detect spoilages presence. A total of 500 spectra were acquired for detecting the spoilages presence, 350 were used as a training set, 100 as a test set and 50 as a validation set.

Nir Spectral Data Analysis Methods and Model Developing

NIR analysis of tomato juice can be run in two main ways (**Fig. 4**): 1) qualitative or 2) quantitative. 1) Qualitative analysis with NIR used to discriminate between samples with Principal Component Analysis (PCA) by building classes of samples.

Partial Least Squares (PLS) Regression

PLS can also be expressed as, a projection on latent structures, is a recent technique that combines features from and generalizes PCA and multiple linear regression. Its goal is to predict a set of dependent variables from a set of independent variables or predictors. This prediction is achieved by extracting from the predictors a set of orthogonal factors called latent variables which have the best predictive power. These latent variables can be used to create displays akin to PCA displays. The quality of the prediction obtained from a PLS regression model is evaluated with cross-validation techniques such as the bootstrap and jackknife. There are two main variants of PLS regression: The most common one separates the roles of

Fig. 2 Tomato processing flowchart

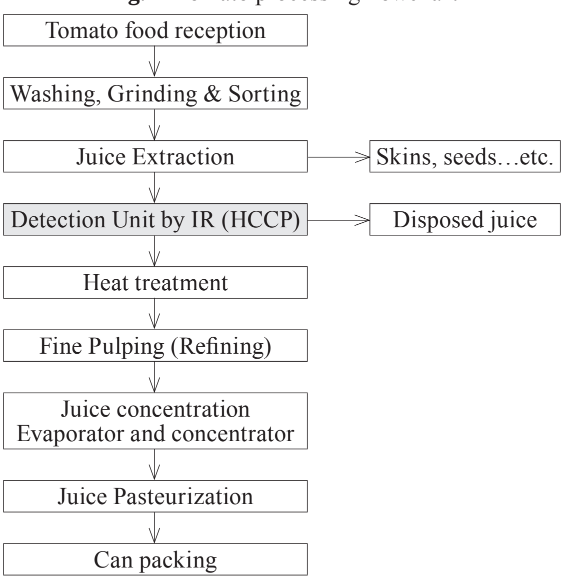
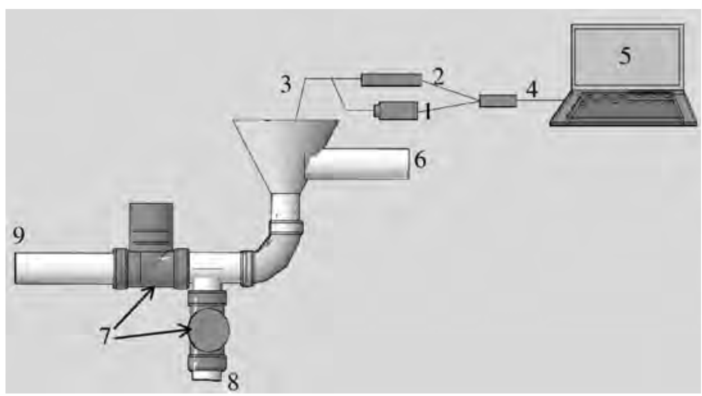


Fig. 3 IR monitoring unit consists



1: light source, 2: Ocean optics USB 2000, 3: optical fiber bundle head, 4: NI-DAQ 6008, 5: Labtop, 6: tomato juice entered, 7: two automatic valves (controlled by servo motors), 8: spoiled juice outlet, 9: heat treatment unit

Fig. 4 Blocks diagram of qualitative and quantitative analysis

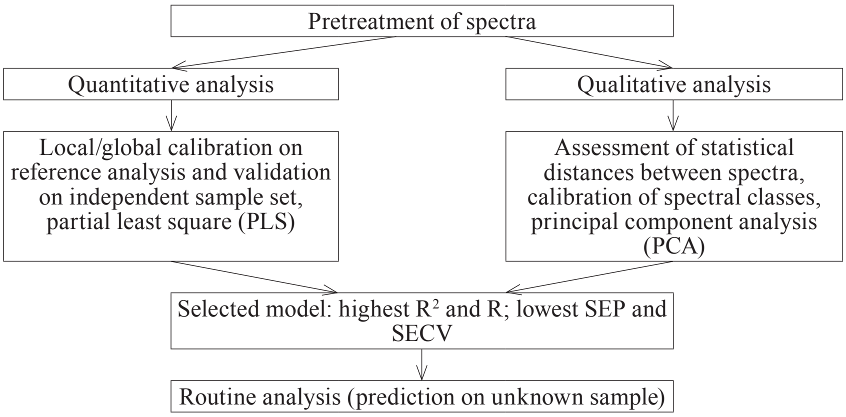


Table 1 Tomato fruits categories

Firmness classes	Sorting scale	Tomato juice discrimination
Firm	0 − 10	Fresh
Soft	10 < −18	Fresh
Very soft	18 < −30	Spoiled

dependent and independent variables; the second one —used mostly to analyze IR data— gives the same roles to dependent and independent variables. PCA is a mathematical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. The number of principal components are less than or equal to the number of original variables. This transformation is defined in such a way that the first principal component has the largest possible variance (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible under the constraint that it be orthogonal to (i.e., uncorrelated with) the preceding components. Principal components are guaranteed to be independent only if the data set is jointly normally distributed. PCA is sensitive to the relative scaling of the original variables. VIP statistically represents the value of each predictor in fitting the PLS model for both predictors and responses. Values lower than 0.8 are considered to have small contribution to the prediction (Wold, 1995).

Validation

Once a calibration model is developed, it must be validated with samples that are independent from those used in developing the calibration because the model with the best calibration statistics may not be the best model for prediction. The goal is to obtain a calibration that has residual differences as close to zero as possible between the NIR predicted data and reference method data. The smaller the values of residual differences, the more accurate are the results that can be obtained by the calibration model. The correlation coefficient of prediction (R) measures how closely the NIR predicted data and reference method data are related for validation samples. The SEP measures the residual between the NIR predicted data and reference method data. The best calibration model to be used for prediction is the one with the highest R and lowest RMSD values. In addition, the RPD (ratio of SD to SEP) value is a simple statistic that enables the evaluation of SEP in terms of the SD of the reference data of the prediction set, and allows comparison of results obtained from sets of data expressed in different ranges or units (Williams, 2001).

Where;

SECV: standard error of cross-validation performed on the calibration data set.

SEP: standard error of prediction which is the standard deviation (SD) of differences between NIR reflectance and reference values, that should be calculated on real independent data set, but is usually calculated on a non-independent validation data set.

RMSD: root mean square of difference.

RPD: the ratio of performance to deviation, (SD of reference values) / SEP.

R^2: the coefficient of determination.

Results and Discussion

The measurements show increasing deformation with increasing fruit maturity (**Fig. 5**), the values of sorting scale (SS) not acquired until 5 seconds elapsed. The firmness of whole tomatoes and of pericarp tissue progressively decreased ($P < 0.01$) with ripening (**Fig. 6**).

Tomato fruits were graded and categorized according to its firmness; the fruit softness is used as an indicator of tomato (Lycopersicon esculentum) quality given in **Table 1**.

Two hundred spectral signatures were acquired from spoiled and fresh tomato juices. The higher spectral difference between spoiled and fresh signatures was noted in the 670-950 nm range and no substantial differences were present above 700 nm (**Fig. 7**). The XLSTAT 2013 software was used, to determine the best discriminant wavelengths PLS and VIP.

The principal component discriminant analysis (PC-DA) shows two principal components of discriminant coordinates for the spectral data creating a new coordinate system; the greatest variance of the data comes to lie on the first coordinate (called the first principal component ‹PC_1›), contributing 97.48 %

of the whole data while the second greatest variance on the second coordinate (called the second principal component ‹PC_2›) represent 1.34 % (**Fig. 8**). The reflectance signatures acquired by wavelengths 1000 and 990 nm contribute the majority of 1.18 % of whole data which cannot be discriminated by neither PC_1 nor PC_2. It was seen as the points closest as possible to the principal components coordinates, the reflectance signature could be completely discriminated by the model.

Fig. 8 shows the PCA bi-plot (representing both the variables and the samples) of the "sorting scale". The sorting scale evolution is evident along the first two principal components; on PC1, samples are distributed from right to left according to the sorting scale. PLS is a quick, efficient and optimal for a criterion method based on covariance. It is recommended in cases where the number of variables is high, and where it is likely that the explanatory variables are correlated. The developed discriminant **Eqns. 2** & **3** were obtained by PLS discrimination analysis. The model parameters are listed in **Table 2**.

$$F = intercept + \sum_i^p b1_i R_i \text{............} (2)$$

$$F = intercept + \sum_i^p b2_i R_i \text{............} (3)$$

Where: F is the fresh and S is the spoiled juices; and R is the reflectance at the wavelength denoted by the number i. The spectrophotometer acquired the signature from each class of tomato juice of the trial group to determine the detection accuracy provided by the discriminant equations (***Eqns. 2*** & **3**). The model parameters were illustrated in **Table 2**. The output value from each equation ranged between 0 and 1 and when **Eqn. 2** exceeded 0.5 the tomato was considered fresh. The spectral measurements from fresh juices were introduced to **Eqn. 2** and 81 % of the fresh juices were properly classified. Spoiled juice was successfully detected on 75 % of the infected tomatoes when **Eqn. 3** exceeded a value of 0.5. The achieved correlation coefficient (R) for training and validation was 0.998 and 0.86, respectively which suggested that the NIR spectral discrimination system could be used as a simple and rapid technique for absolving the task (**Fig. 9**). The cross-validation results using raw, first derivative, and second derivative data provided a prediction error of 12-14 %. The best validation performance was 0.0017229 at epoch 4 (**Fig. 10**).

VIP statistic of IR variables was studied (**Fig. 11**). It was seen that the higher VIP values corresponded to the 510, 660 and 690 nm means that these wavelengths have more impor-

Fig. 5 Deformation results on tomato fruit subjectively categorized into three firmness classes

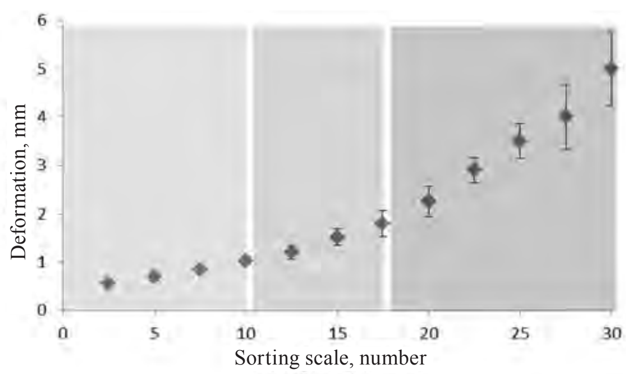


Fig. 6 Changes in firmness during 12 days of ripening

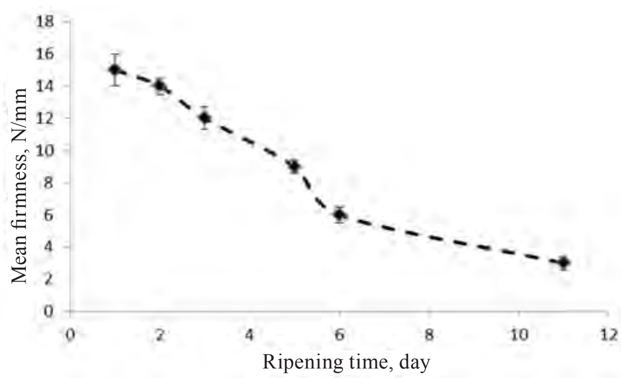


Fig. 7 Spectral signature at different sorting scales

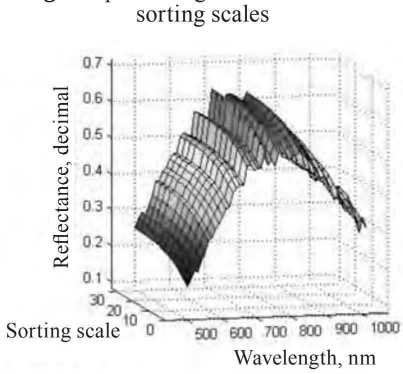


Fig. 8 Bi-plot PCA on NIR spectra

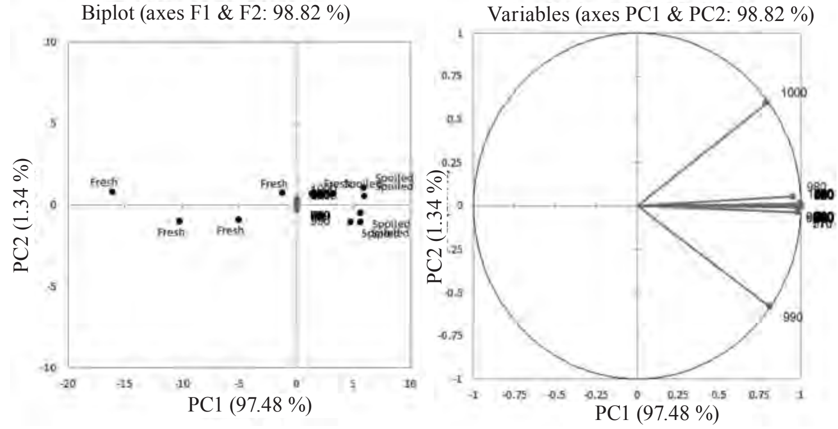
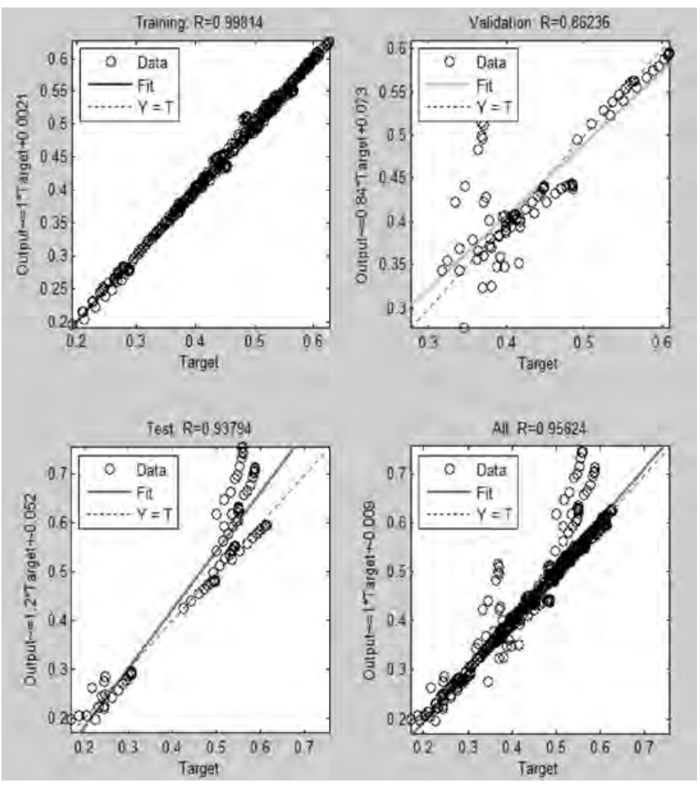


Table 2 Discriminant model parameters

Intercept	Fresh	Spoiled	Variable	Fresh	Spoiled
	11.322	−10.322		b_1	b_2
Variable	b_1	b_2	R_{750}	40.941	−40.941
R_{500}	−11.882	11.882	R_{760}	−11.882	11.882
R_{510}	21.071	−21.071	R_{770}	21.071	−21.071
R_{520}	−12.685	12.685	R_{780}	−12.685	12.685
R_{530}	9.987	−9.987	R_{790}	9.987	−9.987
R_{540}	−20.724	20.724	R_{800}	−20.724	20.724
R_{550}	−7.730	7.730	R_{810}	−7.730	7.730
R_{560}	−15.459	15.459	R_{820}	−15.459	15.459
R_{570}	−26.526	26.526	R_{830}	−26.526	26.526
R_{580}	−15.268	15.268	R_{840}	−15.268	15.268
R_{590}	−23.844	23.844	R_{850}	−23.844	23.844
R_{600}	−11.582	11.582	R_{860}	−11.582	11.582
R_{610}	−5.484	5.484	R_{870}	−5.484	5.484
R_{620}	7.552	−7.552	R_{880}	7.552	−7.552
R_{630}	−11.505	11.505	R_{890}	−11.505	11.505
R_{640}	−14.052	14.052	R_{900}	−14.052	14.052
R_{650}	−24.945	24.945	R_{910}	−24.945	24.945
R_{660}	−70.177	70.177	R_{920}	−70.177	70.177
R_{670}	12.668	−12.668	R_{930}	12.668	−12.668
R_{680}	18.751	−18.751	R_{940}	18.751	−18.751
R_{690}	108.930	−108.930	R_{950}	108.930	−108.930
R_{700}	17.638	−17.638	R_{960}	17.638	−17.638
R_{710}	21.018	−21.018	R_{970}	21.018	−21.018
R_{720}	4.742	−4.742	R_{980}	4.742	−4.742
R_{730}	0.290	−0.290	R_{990}	0.290	−0.290
R_{740}	19.850	−19.850	R_{1000}	19.850	−19.850

Fig. 9 Discriminant model calibration and validation



tance in discrimination process and 730 nm had lower VIP values.

Conclusions

The spoiled juice can be detected with high efficiency using optical reflectance. The developed control point is reliable, cheap and quick and does not require the presence of liquids to detect tomato infection. Normal laboratory techniques require one day detecting the spoilages which cannot be visually identified. Proper and periodical inspections before filling trailer containers and at storage rooms can help to maintain tomatoes within quality tolerances reducing post-harvest losses before reaching the consumer. In the future, one sensor will be required that will be sensitive enough to discriminate among bacterial infections in tomatoes.

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Fig. 10 The best validation performance

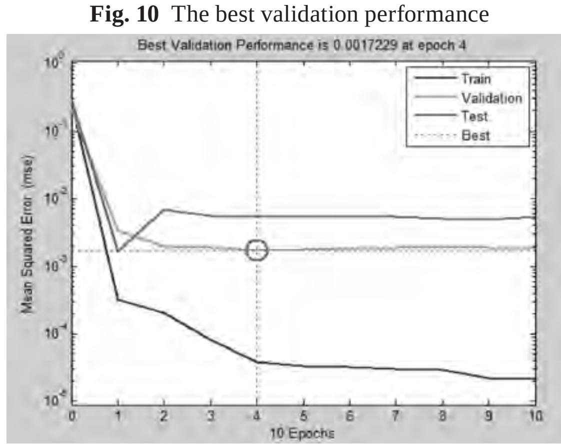

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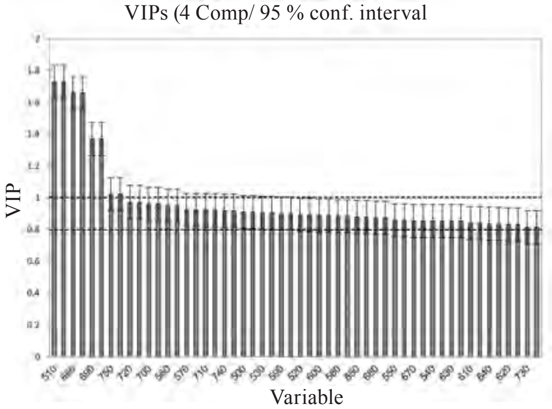
Fig. 11 Variable importance projection for each spectral wavelength

VIPs (4 Comp/ 95 % conf. interval



Mechanization of Mulch Laying Process —A Boon in Sustaining Global Agricultural Production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Abstract

Plastic mulches have various beneficial effects on crop production, including an increase in soil temperature, conservation of soil moisture, texture and fertility; and the control of weeds, pests and diseases. This technology is not only helping to alleviate the issue of climate change but also helping farmers to increase yield, thereby high economic returns for the better quality produce. Challenges faced for commercialization of plastic mulches were lack of mechanization and intensive labour requirement. Tractor mounted mulch laying machine acquired reasonable acceptance in the developed world while its adaptation was limited in developing world particularly South East Asia. Benefit cost analysis of adapting mulch laying machine for viable use was done. Three options such as manual, partially mechanized, and mechanized process of mulch laying were analyzed. The analysis revealed that total operational cost of the machine is INR Rs. 2129/ ($ 36) per hectare with saving of 31.78 % with partially mechanized (Bed planter + Manual Mulch + Manual Drip Laying) and 68.8 % with completely manual operation. Plastic mulching machine also saves 81.43 % and 95.20 % labour over partially mechanized operation and completely manual operation respectively.

Keywords: Mulches, mulch mechanization, cost economics, synthetic mulches.

Introduction

The role of agricultural mechanization is important in promoting conservation and precision agricultural techniques. The main purposes of the mechanization are to make efficient use of labour, increase the land productivity and to decrease the cost of production (stout et. al. 1999). Modern agricultural mechanization techniques can help proficiently handle the of field processes, improve farm working conditions and to improve socio-economic status of the farmers. Han *et al.* (2013) reported that the present contribution of agricultural mechanization to agricultural output is 31.46 % of all the factors and recommended that increase in agricultural mechanization will contribute to the growth of agricultural output. Out of various mechanization processes needed at the farm, mechanization of mulch laying process is the important one. Plastic mulches have various beneficial effects on crop production (Hartwig *et al*., 2002). These benefits include increase in soil temperature, conservation of soil moisture, texture and fertility; and the control of weeds, pests and diseases (Singh *et al*., 1992; Franczuk *et al*., 2010; Skorka *et al*., 2013). Beside multiple benefits, mulching was not adapted by the farmers because of high labour requirement in manual laying of plastic mulch at a large scale. In South East Asia, rice straw is the traditional mulch material while plastic as mulch material is considered advance mulch material. Tractor mounted mulch laying machine got reasonable acceptance in the developed world while its adaptation was limited in South East Asia. Similarly, beyond established importance of plastics material, it is still not commercially popular as mulch in the developing countries.

Mulching is a complex basket of interrelated practices (Olaf, 2003) so clear understanding of mulch laying cost is very important. Beside several benefits, literature is almost silent in comparing the cost of manual and mechanized mulch laying operations. Explicit challenges faced for commercialization of plastic mulches were lack of cost comparison between manual laying of plastic, partially mechanized and fully mechanized laying of plastic mulch. Accordingly, objective of this manuscript is to introduce the

Table 1 Brief specification of the machine

Parameter	Observation
Power source	40-50 hp tractor
Type of machine	Tractor drawn, mounted type
Overall dimension (L × W × H), cm	220 × 185 × 220
Provision for punching • Lateral, cm • Longitudinal, cm	Provided
Bed height, cm	Adjustable (15-20)
Type of attachment for plastic sheet	Roller
Sheet covering fender	

Table 2 Field performance of tractor drawn bed former cum plastic mulch laying machine

Parameter	Observation
Power source	45-50 hp tractor
Type of machine	Tractor drawn, mounted type
Forward speed, km/h	3.19
Field capacity, ha/h	0.24
Field efficiency, %	55
Slip, %	13.72
Fuel consumption, l/ha	4.18
Dimensions of bed, cm • Top • Bottom • Height • Slant	 55 100 18 25
Lateral punch spacing, cm	45
Longitudinal punch spacing, cm	40
Plastic mulch used, kg/ha	290
Damage to plastic mulch	Nil
Labour required with machine	3 persons (including tractor operator)

benefits of adapting mulch laying machine and formulate recommendation for viable use by analyzing cost of fully mechanized mulching system, partially mechanized (Bed planter + Manual Mulch + Manual Drip Laying) and completely manual operation. For the this purpose a machine manufactured in India having cost of INR 67000/ was purchased by Department of Soil and Water Engineering, Punjab Agricultural University, Ludhiana, India, for its performance evaluation.

Machine Description

Tractor drawn mulch laying machine accomplishes four operations in one pass. These operations are: bed forming, laying of drip pipe, laying of plastic sheet to act as mulch and punching the plastic sheet at the desired spacing for transplanting of nursery. Machine can lay plastic sheet of different width ranging from 75 to 135 cm (i.e. 75 cm, 90 cm, 105 cm, 120 cm, 135 cm) on single wide bed and requires a minimum of 40-50 hp tractor to operate the machine. The height of the bed can also be adjusted from 15 cm to 20 cm.

Stationary view of tractor mounted plastic mulch laying machine (**Fig. 1**) shows: bed former, drip pipe, role of plastic sheet (mulch) and punching wheels. Depth of bed can be adjusted by depth control wheel. Similarly, **Fig. 2** displays operation of tractor mounted plastic mulch laying machine. Machine operation clearly indicates uniform spread of plastic sheet of bed with punches for seedling or transplanting.

Table 1 covers brief specifications of mulch laying machine. Machine feature to mount on tractor can facilitate in transporting machine from field to storage yard. Overall dimensions within the range of 185-220 cm suggests safe in transportation and adjustable bed height can help accommodate crop need and soil type.

Table 2 shows the operational parameters along with some results of machine performance such as field capacity, fuel consumption, size of formed bed and spacing of punches. The tractor power required for the machine is within the range of 40-50 hp which is a commonly used tractor in India.

Dimensions of the beds formed by mulching machine were as follows: top of the bed was 55 cm, bottom was 100 cm, height 18 cm and slant was 25 cm and these dimensions of the beds are within the acceptable range set by New South Wales (NSW), Australia (Beecher *et al*., 2003).

Fig. 1 Stationary view of the tractor mounted plastic mulch laying machine

Fig. 2 Tractor mounted plastic mulch laying machine in operation

Results and Discussions

Effect of Tractor -Plastic Mulching Machine on Yield and Water Use Efficiency of Egg Plant

The machine was tested to assess its performance in the field. In this respect, an experiment was conducted at the research farm of Ludhiana Agricultural University during 2012 to study the effect of mulching on yield of eggplant under different levels of irrigation. Major nutrients of inorganic fertilizer such as nitrogen, phosphorus and potash, NPK (80 % of RDF) were applied

Table 3 Yield of eggplant crop transplanted with mulching machine for different irrigation treatments

Treatments	Yield of eggplant crop (q/ha) {q = quintal (100 kg)}				
	I_1	I_2	I_3	Mean	Conventional Method
Mulch	683.68	755.83	585.18	674.90	
Non-mulch	589.75	558.00	566.83	571.55	437.63
Mean	636.70	656.90	576.00		
CD (p = 0.05)	M = 49.00 I = 50.30 I × M = 71.15				

Table 4 Comparison of different irrigation level upon efficiency and saving of water

Irrigation treatment	Yield (q/ha)		Total depth of water applied (cm)	Water use efficiency (ton/ha-cm)		Water saving over furrow irrigation (%)
	Mulched	Non-mulched		Mulched	Non-mulched	
I_1	683.68	589.75	53.09	1.29	1.11	30.03
I_2	755.83	558.00	42.47	1.78	1.31	44.03
I_3	585.18	566.83	31.86	1.84	1.78	58.01
Conventional (furrow irrigation)		437.63	75.88		0.58	

Table 5 Operational cost of plastic mulch laying machine and bed planter

Title	Tractor 45-50HP	Mulching machine	Bed Planter
New cost, P	500000	67000	35000
Life (yrs), L	15	15	15
Avg. use/yr (h)	700	240	240
Rate of interest (%), i	12	12	12
Field capacity, ha/h		0.24	0.3
Salvage value, S=10% of P	50000	6700	3500
Annual Fixed Charges			
Depreciation (Rs/yr)	30000	4020	2100
Interest cost (Rs/yr)	33000	4422	2310
Taxes, insurance and shelter (Rs/yr) = 2 % of P	10000	1340	700
Total fixed costs (Rs/yr)	73000	9782	5110
Total fixed costs (Rs/h)	104.29	40.76	21.29
Variable Costs			
Fuel required (l/h)(depend on implement	0	4.18	4.18
Labour required with machine	1	2	0
Labour cost, Rs/h	33	26.25	26.25
Repair & maintenance (Rs/h)	35.71	13.96	7.29
Fuel cost (Rs/h) @ Rs46/l	0	192.28	192.28
Cost of lubricants (Rs/h) = 20 % of fuel cost	0	38.456	38.456
Labor cost (Rs/h)	33	52.5	0
Total variable cost (Rs./h)	68.71	297.19	238.03
Total Costs			
Total cost (fixed + variable) (Rs/h)	173.00	337.95	259.32
Total cost, Rs/ha including tractor		2128.97	1441.06
Labour required off machine operation, man-h/ha		0	0
Grand Total machine Cost, Rs/ha		2128.97	1441.06

through fertigation with 20 % in the first month after transplantation and remaining fertilizer was applied in split doses till first week of December. The irrigation was carried out every 2nd day and fertigation was done on every 4th day. The row to row and plant to plant spacing was 45 and 40 cm, respectively on a bed. All the mulched treatments gave higher yield as compared to the non-mulched drip irrigation treatments as well as furrow irrigation method.

Table 3 summarizes the effect of different treatments on the yield of eggplant crop transplanted with mulch laying machine. The yields of eggplant crop written in the table were obtained through different irrigation treatments using mulch and non-mulch options. Three replicates were completed for each treatment. All values listed in the **Table 3** have high level of significance, based on p-value ≤ 0.05 which is reasonable. In the table symbols I_1 means Irrigation at 1.0 times of potential evapotranspiration (PET), I_2: Irrigation at 0.8 times PET, and I_3: Irrigation at 0.6 times PET).

Table 3 also shows that in all cases yield of eggplant with drip irrigation system was higher than the conventional method. The highest yield of eggplant crop was obtained 755.83 q/ha under the mulched treatment with I2 irrigation level while eggplant yield with non-mulch drip irrigation was 558.0 q/ha and 437.63 q/ha with conventional method of irrigation. This indicates that yield of eggplant with I2 irrigation level was 72.71 % higher than the conventional method of irrigation and 35.45 % higher than the non-mulch drip irrigation method. Hence, drip irrigated mulched crop gave significantly higher yield as compared to drip irrigated non mulched crop. In further detail, mulched treatments on an average resulted in 103.35 q/ha higher yield as compared non mulched treatments and 237.28 q/ha more yield as compared to furrow method of irrigation. Comparison of water use efficiency and water saving with mulch and non-mulch treatment was also made. **Table 4** shows comparison of different irrigation levels upon water use efficiency and water savings.

Drip irrigation at 0.6, 0.8 and 1.0 times PET resulted in mean water saving of 58.01, 44.03, and 30.03 % respectively over conventional method of irrigation. In all cases, mulched treatments resulted in higher water use efficiency (1.29 for I_1, 1.78 for I_2, 1.84 for I_3) than non-mulched treatments in which water use efficiency was 1.11 for I_1, 1.1.31 for I_2, 1.78 for I_3. Irrigation level of I3 showed highest saving of water but yield was the highest in case of I_2 and water use efficiency for mulched treatment is comparable for the both levels of I_2 and I_3. This finding suggests that the irrigation at 0.8 times of potential evapotranspiration with mulched treatment is the best among the tested options.

Cost Economics of Mechanized Mulch Laying Process

The economics of any new technological advancement plays an important role in its adoption by end users. Three options such as manual mulching (all four processes manual), partially mechanized (beds made with bed planter and remaining processes manual), and completely mechanized (all four processes completed by the machine) were analyzed. The analysis revealed that total operational cost of the machine is INR Rs. 2129/ ($ 36/) per hectare (**Table 5**). Cost analysis showed saving in cost of operation was 31.78 % with partially mechanized (Bed planter + Manual Mulch + Manual Drip Laying) and 68.8 % with completely manual operation. Plastic mulching machine saves 81.43 % and 95.20 % labour over partially mechanized operation (Bed planter + Manual Mulch + Manual Drip Laying) and completely manual operation respectively (**Table 6**).

Table 6 Comparative economic analysis of mulch laying machine with manual mulch laying process

Operation	Labour requirement, man-h/ha	Cost of operation, Rs./ha	Saving of labour, %	Saving in cost, %
Mulching machine	12.5	2129	95.2 (81.43)*	68.80 (31.78)*
Partially mechanized (Bed planter + Manual Mulching + Drip \ Laying)	3.33 + 44 + 20 = 67.33	1441+ 1680 (@64 man-h/ha) = 3121	74.10	54.27
Complete manual operation (Bed forming & Mulch Laying + Drip Laying)	240 + 20 = 260	6825 (@260 man-h/ha)	-	-

*Over Partially mechanized operation

Conclusions

The highest yield of 755.83 q/ha was obtained under the mulched treatment with irrigation at 0.8 times of potential evapotranspiration and this yield is 72.71 % higher than the conventional method. Mulching with 0.8 times of PET also showed 44 % saving of water. Saving in cost of operation varies from 31.78 to 68.80 % for partially mechanized operation whereas labour saving varies from 81.43 to 95.20 % for completely manual operation. Thus the mechanization of mulch laying process will proved to be a boon in sustaining global agricultural production by increasing the productivity of land & labour and decreasing the cost of production.

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Status, Challenges and Strategies for Farm Mechanization in India


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Abstract

Economic growth in Indian agricultural sector lags behind growth in industry and services, creating an ever widening rural-urban income gap. Agricultural mechanization plays a key role in improving agricultural production and productivity in developing countries. The average farm size in India is small (1.16 ha) and small and marginal land holdings (less than 2.0 ha) account for 85% of land holdings. Mechanizing small and non-contiguous group of small farms is against 'economies of scale' for individual ownership of farm machinery. The status of farm mechanization in India is analysed by the trend in growth of mechanically power-operated farm equipment over traditional human and animal power operated equipment. It was observed that there was a direct correlation between farm power availability and productivity during the past six decades. Haryana state of India has the highest tractor density per thousand hectare of net seeded area of 84 tractors and followed by 76 tractors for Punjab against all India average of 33 tractors. The sale of transplanter, power weeder, combine harvesters, rotavator and thresher in India is growing at a compound annual growth rate (CAGR) of 50, 50, 28, 20 and 10 %, respectively. The available farm power and productivity in India are expected to reach 2.2 kW/ha and 2.3 t/ha, respectively by the year 2020.

The widely fragmented and scattered land holdings in many parts of the country need to be consolidated to reap benefits of agricultural mechanization. There is a need to innovate custom service or a rental model by institutionalization for high cost farm machinery such as combine harvester, sugarcane harvester, potato combine, paddy transplanter, laser guided land leveller, rotavator etc. to reduce the cost of operation and can be adopted by private players or State or Central Organizations in major production hubs. The farm machinery bank may be established for machines being manufactured elsewhere in the country to supply in low mechanised region on custom hiring basis. Financial assistance or procurement subsidy may be provided for the purchase of agriculture machinery and equipment on individual ownership or custom hiring basis.

Keywords: Mechanization, Farm power, Mechanization strategy, Tractor density.

Introduction

India accounts for only about 2.4 % of the world's geographical area and 4 % of its water resources, but has to support about 17 % of the world's human population and 15 % of the livestock. Agriculture is an important sector of the Indian economy, accounting for 14 % of the nation's GDP and about 11 % of its exports. Agriculture in India is currently growing at an average compound annual growth rate (CAGR) of 2.8 %. There was a record food grains production of 264.4 million tonne during 2013-14 (FAO, 2014). About half of the population still relies on agriculture as its principal source of income and it is a source of raw material for a large number of industries. Accelerating the growth of agriculture production is therefore necessary not only to achieve an overall GDP target of 8% and meet the rising demand for food, but also to increase incomes of those dependent on agriculture and thereby ensure inclusiveness in our society (Anonymous, 2013).

Agricultural mechanization technology plays a key role in improving agricultural production in developing counties, and should be considered as an essential input to agriculture (Rasouli *et al*., 2009). The term 'farm mechanization' is used as an overall description of the application of the variety of tools, implements, equipment, machinery, power and other mechanical inputs. Proper use of mechanized inputs into agriculture has a direct and significant effect on production, productivity and profitability on agriculture farms, along with labour productivity and quality of life of people engaged in agriculture (Bishop, 1997; Clarke, 2000). Empirical evidence confirms that there is a strong correlation between farm mechanization and agricultural productivity. States with a greater availability of farm power show higher productivity as compared to others (Singh *et al.*, 2011).

Increasing demand for industrialization, urbanization, housing and infrastructure is forcing conversion of agricultural land to non-agricultural uses. The scope for expansion of the area available for cultivation is limited. According to agriculture census 2010-11, small and marginal holdings of less than 2 hectare account for 85 % of the total operational holdings and 44 % of the total operated area. The average size of holding for all operational classes (small and marginal, medium and large) has declined over the years and has come down to 1.16 hectare in 2010-11 from 2.82 hectare in 1970-71 (Anonymous, 2013).

A few authors have studied the status of farm mechanization with reference to the intensity of power or energy availability, and its impact in increasing agricultural and labour productivity (Singh, 2006; Van den Berg *et al.*, 2007). Giles (1975) reviewed power availability in different countries, and demonstrated that productivity was positively correlated with potential unit farm power. The NCAER (1981) assessed the impact of tractorisation on the productivity of land (yield and cropping intensity), and economic growth (income and employment). Binswanger (1982) defined the status of mechanization by the growth of mechanically power-operated farm equipment over traditional human and animal power operated equipment. Rijk (1989) reviewed the growth of mechanization in different Asian countries, and suggested for the formulation of strategy for mechanization policy based on economics of use of animate and mechanical power for different field operations.

Table 1 Population dynamics of Indian agricultural workers (No. in million)

Particulars	1991	2001	2011	2020 (Projected)
Country's population	846.4	1028.7	1210.7	1323.0
Total no. of workers	313.7	402.2	481.7	566.0
No. of workers as % of population	37.1	39.1	39.8	42.8
No. of agricultural workers	185.3	234.1	263.0	230.0
Cultivators	110.7	127.3	118.7	110.0
Agricultural labourers	74.6	106.8	144.3	120.0
Percentage of agricultural workers to total workers	59.1	58.2	54.6	40.6
Percentage of females in agricultural work force	35.1	39.0	37.2	45.0

This paper discusses the relevant background information on population dynamics, socio-economic status, status of availability of farm power and machinery, and challenges and strategies for mechanization of Indian agriculture.

Socio-Economic Status of Agricultural Workers

The availability of labour to work in agriculture is crucial in sustaining agricultural production. The population dynamics of Indian agricultural workers shows that by 2020, the population of agricultural workers in the country will be about 230 million of which 45 % will be the female workers (**Table 1**). It is predicted that the population in rural areas will decrease to 62.83 % in 2025 and to 44.83 % in 2050 (Soni and Ou, 2010). Thus, there is going to be a significant role of farm workers in country's agricultural production. Agricultural wages have traditionally been low, due to low productivity and large disguised unemployment in agriculture sector. However, in recent years there is sharp increase in agricultural wages due to economic growth and adoption of employment generation policy like the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) and increase in minimum wages due to the Minimum Wages Act. However, agricultural wages, in general, are still much lower than the industrial wages. This further strengthens the necessity for agricultural mechanization in a manner that is inclusive and suitable for Indian conditions.

Women in rural India play a major role in shaping the economy of the country. In Indian agriculture, women perform four different types of roles viz. as a worker (a source of power), as an operator (a controller), as a manager (a farmer) and as an entrepreneur (a business person). At present, most of the Indian women carry out the role of workers only. The hand operated tools/equipment available have been primarily developed for male workers, and women workers have to use these whenever required. As a result, the output is lower and may lead to many occupational health problems. To make them capable for other roles, it is necessary to design machines suitable to them and upgrade their skill for operating these machines. Also for the roles of manager and entrepreneur, their knowledge base will have to be suitably updated.

Farm Power Availability

Agricultural workers, draught animals, tractors, power tillers, diesel engines and electric motors are used as sources of farm power in Indian agriculture. **Table 2** shows

Table 2 Farm power availability from different sources in India

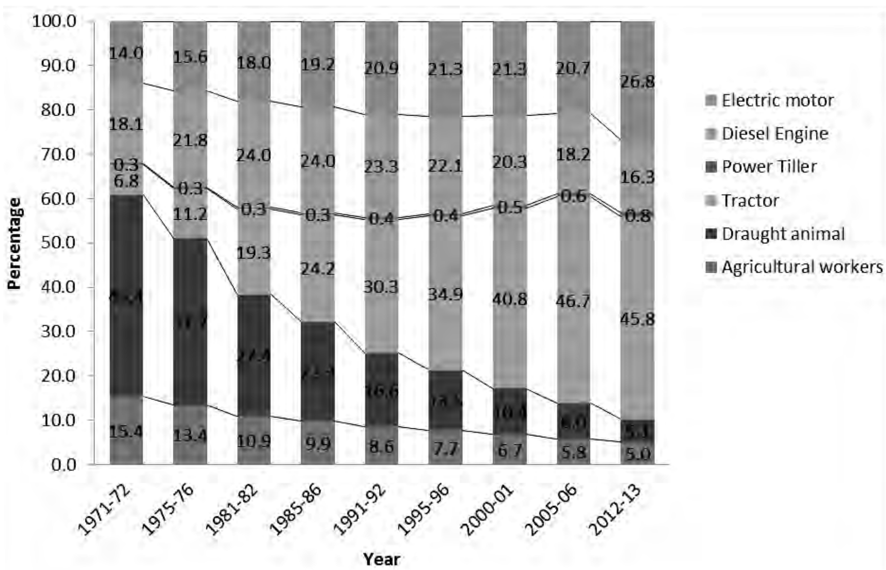
Year	Farm power, kW/ha						Total power, kW/ha
	Agriculture workers	Draught animals	Tractors	Power tillers	Diesel engines	Electric motors	
1971-72	0.045	0.133	0.020	0.001	0.053	0.041	0.293
1975-76	0.048	0.135	0.040	0.001	0.078	0.056	0.358
1981-82	0.051	0.128	0.090	0.002	0.112	0.084	0.467
1985-86	0.057	0.129	0.140	0.002	0.139	0.111	0.578
1991-92	0.065	0.126	0.230	0.003	0.177	0.159	0.760
1995-96	0.071	0.124	0.320	0.004	0.203	0.196	0.918
2001-02	0.079	0.122	0.480	0.006	0.238	0.250	1.175
2005-06	0.087	0.120	0.700	0.009	0.273	0.311	1.500
2011-12	0.100	0.119	0.804	0.014	0.295	0.366	1.698
2012-13	0.093	0.094	0.844	0.015	0.300	0.494	1.841

Table 3 Cropping intensity and power availability on Indian farms

Year	Cropping intensity, %	Productivity, t/ha	Power available, kW/ha	Power per unit production, kW/t	Net sown area per tractor, ha
1975-76	120	0.94	0.36	0.38	487
1985-86	127	1.18	0.58	0.49	174
1995-96	131	1.50	0.92	0.61	84
2005-06	132	1.65	1.50	0.91	47
2010-11	141	1.92	1.68	0.88	31
2012-13	141	2.06	1.84	0.89	30

the available farm power (kW/ha) in Indian agriculture from these sources and total farm power. It indicates that the composition and relative share of different sources of power for farming operations have undergone significant change during the last four decades. The availability of draught animals power has come down from 0.133 kW/ha in 1971-72 to 0.094 kW/ha in 2012-13, whereas the share of tractors, power tillers, diesel engines and electric motors has increased from 0.020 to 0.844, 0.001 to 0.015, 0.053 to 0.300 and 0.041 to 0.494 kW/ha, respectively during the same period. The total power availability on Indian farms has increased at a CAGR of 4.58% from 0.293 to 1.841 kW/ha during the last forty one years.

Fig. 1 Trend in use of power sources in Indian agriculture



The percentage share of agricultural workers and draught animal power sources in total power reduced from 15.4 to 5.0 % and 45.4 to 5.1 %, respectively over the years from 1971-72 to 2012-13 (**Fig. 1**). The combined share of agricultural workers and draught animals in total farm power availability in India reduced from 60.8 % in 1971-72 to 10.1% during 2012-13. On the other hand, the share of tractor and electric motor in farm power availability increased from 6.8 to 45.8 % and 14 to 26.8 %, respectively during the last 41 years. The share of tractor power was maximum and increased by 39 % during the period. The share of diesel engine was almost the same over the years from 1971-72 to 2012-13. The share of power tiller is less than one percent during the period in spite of small size farms in India.

Cropping Intensity and Power Availability

The cropping intensity in Indian agriculture increased with increase in power availability (**Table 3**). It was 120 % with power availability of 0.36 kW/ha during 1975-76 and increased to 141 % with increase in power availability to 1.84 kW/ha during 2012-13. Net sown area per tractor indicated the reverse trend during the same period, which was 487 ha/tractor in 1975-76 and reduced to 30 ha/tractor in 2012-13. The power availability per unit production increased from 0.38 kW/t in 1975-76 to 0.89 kW/t in 2012-13 during last thirty seven years. There may be many reasons including rainfall, crop varieties, timely use of tractors, electricity availability etc. in increasing the food grain productivity during the period.

The farm power availability and productivity increased from 0.25 to 1.84 kW/ha and from 0.52 to 1.92 t/ha, respectively over the years from 1951 to 2012 (**Fig. 2**). It has been observed that farm power availability and food grain productivity have a direct relationship (r^2 = 0.986) during the last six decades (**Fig. 2**). Similar trend was observed by Giles (1975). The predicted values of farm power availability and productivity in India are 2.2 kW/ha and 2.3 t/ha, respectively for the year 2020.

Status of Farm Mechanization

The Indian agricultural equipment market is experiencing a rapid growth with expected strong potential for future growth as well. The demand for agricultural machinery in Asia-Pacific region was more than twice than in any other region. In Asia-Pacific region, India has remained one of the primary nations which fuelled the growth of the market for tractors, power tillers and agricultural equipment.

Tractor and power tiller

The sale of tractors in India has grown at a CAGR of 10.64 % from 217,456 in 2001-02 to 661,431 in 2012-13 during the last 11 years. The Indian tractor market has traditionally been dominated by 23-30 kW tractor segment. Based on the power, sale of tractors in India during the last 13 year is shown in **Fig. 3**. The trend shows that sale of more than 37 kW tractors increased from 7.3 % to 13.8 % during the last thirteen years (2000-2013). Similarly, the sale of tractors in the range of 31-37 kW increased from 14.1 to 36.4 % during the same period. It indicates that requirement of higher power category tractors in India increased for using high capacity machines on custom hiring basis. During the same period, the sale of medium power tractors (23-30 kW) decreased from 55.0 to 40.4 % and low power tractors (15-22 kW) from 23.0 to 6.3 %. The sale of less than 15 kW tractors was only 3.13 % during 2012-13. The present trend in sale of tractors in different power range in India indicates the highest share of 40.4 % for 23-30 kW category tractors. Haryana state of India has the highest tractor density of 84 tractors per thousand hectare of net sown area and followed by Punjab (76), Uttar Pradesh (51), Bihar (44), and Tamil Nadu (43) states. Overall tractor density per thousand hectare of net sown in India is 33. The lowest tractor density is in Kerala (4) and followed by Assam (9), and West Bengal (17) among the states of India.

The relationship between tractor

Fig. 2 Trend of farm power and agricultural productivity from 1952 to 2012

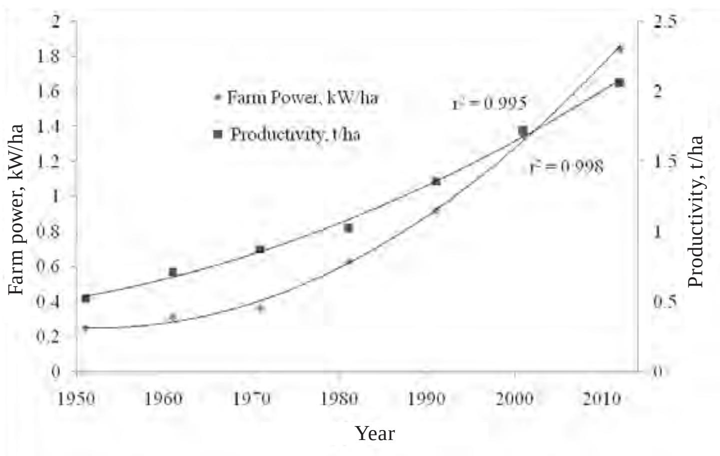
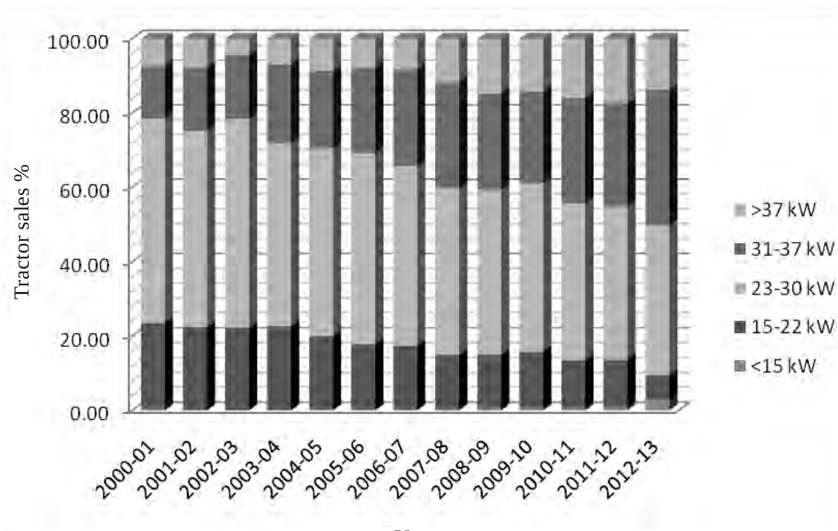


Fig. 3 Power wise sale trend of tractors in India



density and productivity in major states of India is shown in **Fig. 4**. The lines of average tractor density (33 tractors/1000 ha) and average foodgrain productivity (2.06 t/ha) are superimposed on **Fig. 4** to divide these states into four categories i.e., high tractor density and high yield, high tractor density and low yield, low tractor density and low yield and low tractor density and high yield. The first category was of high tractor density and high yield states of Haryana, Punjab, Tamil Nadu (TN), Uttar Pradesh (UP) and Andhra Pradesh (AP). These states utilized maximum tractor power for increasing productivity. The second category is low tractor density and high yield states such as West Bengal (WB) and Kerala. This indicated that these states utilized more human and animal power sources than tractor power source. The third category is high tractor density and low yield states of Bihar and Gujarat. This may be because of lack of awareness on agricultural machinery and tractor usage. The fourth category is of low tractor density and low yield in eight states of Assam, Himachal Pradesh (HP), Odisha, Maharashtra (MH), Jammu & Kashmir (J & K), Madhya Pradesh (MP), Rajasthan (RJ) and Karnataka. This may be due to resource poor farmers and low farm power availability in these states.

Table 4 Market Overview of the major farm machinery used in India

Name of machinery	Market size annually	Approximate cost, US $
Tractor	600,000	7,000-12,000
Power tiller	56,000	2,100
Combine harvester	4,000-5,000	22,000-5,000
Thresher	100,000	1,600-2,500
Rotavator	60,000-80,000	1,300-2,000
Rice transplanter	1,500-1,600	
Walking type		2,500-4,200
Riding type		3,300-16,600
Self-propelled vertical conveyor reaper	4,000-5,000	1,300-2,000
Zero till seed drill	25,000-30,000	750-850
Multi -crop planter	1,000-2,000	850-1,000
Laser land leveller	3,000-4,000	5,800-6,500
Power weeder	25,000	8,500

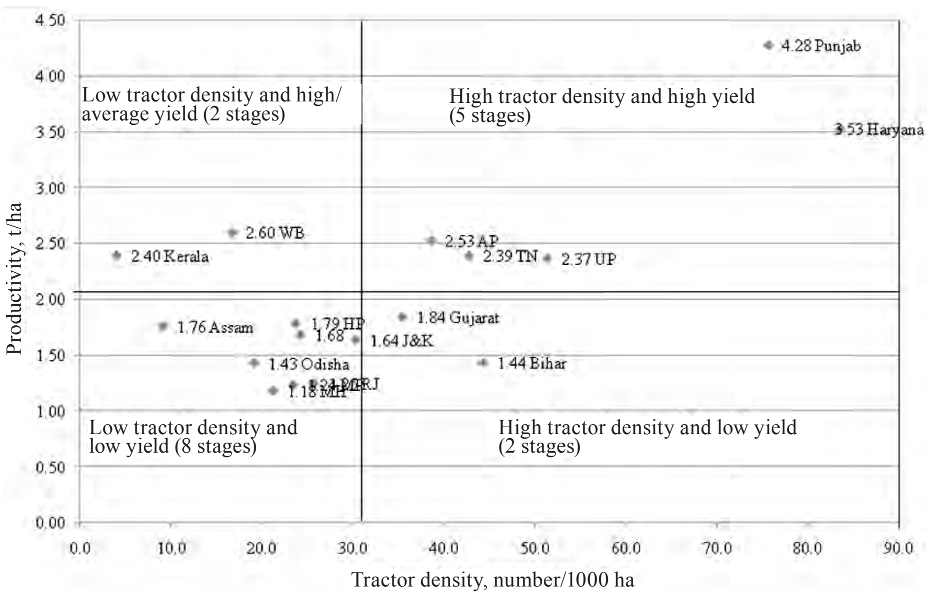
The current market for power tillers in India is estimated at 56,000 numbers during 2013-14. The market for power tillers in India is mainly concentrated in the eastern and southern parts of the country owing to the small land holdings per farmer in these regions and high cultivation of rice crops. Overall power tiller density is 2.21 per thousand hectare of net sown area. The power tillers market in India is dominated by two players from south India these are VST Tillers Tractors Ltd., Bengaluru (Karnataka) and Kerala Agro Machinery Corporation Ltd. (KAMCO), Athani (Kerala).

Farm machinery

The combine harvesters market in India is estimated at 4,000-5,000 units annually by sales which have grown at a CAGR of 28 % since 2006. The tractor mounted combine harvesters occupy around 60 % of the total combine harvesters market in India and is mainly concentrated in southern states viz. Tamil Nadu, Kerala, Andhra Pradesh and Karnataka of the country on custom hiring. This is followed by self-propelled combine harvesters which represent 40 % of the market. Tractor operated combine harvester, costing about 60-70 % of the self propelled combine are owned individually by farmers with large size farms (> 4 ha). The self-propelled combines are largely owned by custom-hiring contractors (Singh, 2004). Punjab, Haryana and Tamil Nadu states have a strong presence in the combine harvester market in India.

Table 4 presents the market overview of the major agricultural machinery used in India. From the table it is estimated that the highest annual requirement is 100,000 for

Fig. 4 Tractor density and productivity in different states of India



threshers and followed by 60,000-80,000 for rotavator, and 25,000 for power weeder. Light weight power weeders are also required for hilly terrains. In case of market growth per annum, the highest growth of 50 % was for rice transplanter. It has been observed that the sale of high cost machinery like combine, laser guided land leveller and rice transplanter is growing fast on custom hiring mode due to more demand.

The market for threshers (multi-crop and paddy), rotavator, planters and zero till drill in India is highly un-organized and is dominated by large number of small and medium scale enterprises (SMEs) located majorly in the states of Punjab, Haryana, Uttar Pradesh, Bihar, Madhya Pradesh, Gujarat, Maharashtra, Tamil Nadu and Andhra Pradesh. The future growth of the threshers market is estimated at a CAGR of 10 % and trend is towards use of tractor operated high capacity threshers on custom hiring mode. The rotavators are being considered better than the conventional tillage equipment among the Indian farmers. The rotavators market in India is growing at a CAGR of 20 %. This equipment saves considerable amount of fuel and accomplishes soil pulverization in short time.

The market for self-propelled (walking and riding type) rice transplanters in India was almost nil 5-6 years back as the rice transplantation was done completely manually with the use of labour. Presently, many companies in India are importing rice transplanters from China and Korea and marketing them in all regions of country. The rice transplanters market in India has grown from about 550 in 2008-09 to 1,500-1,600 units in 2013-14. The industry is expected to grow by more than 50 % in 2014-15 with Chhattisgarh, Odisha, Bihar and southern states showing positive sign of adoption of technology.

The zero till drill is preferred by farmers from Indo Gangetic plains particularly in northern states of India viz Punjab, Haryana and Uttar Pradesh. The sale of zero till drill in India is around 25,000-30,000 per annum in rice-wheat cropping system due to limited time available for sowing of wheat after rice harvesting.

Challenges in Farm Mechanization

Farm Mechanization in India is still in its early stages during the last two decades and is only able to achieve a meagre growth rate of less than 5 %. Even though, higher share of labour (55 %) with lesser contribution to GDP (14 %) with overall mechanization level of 40-45 % makes farming in India less remunerative. The level of mechanization in India is still lower than United State (95 %), Western Europe (95 %), Russia (80 %), Brazil (75 %) and China (57 %) (Renpu, 2014). The average farm power availability in the country is still at a low level as compared to other developing countries like China, Korea and Japan. Unlike other agricultural sectors, farm mechanization sector in India has a far more complex structural composition. It is facing various challenges related to farm machinery and equipment, technology, markets, operations, legislation, policy framework and other related areas. Land size, cropping pattern, market price of crops including Minimum Support Price (MSP), availability of labour and cost of labour are the major factors deciding the agricultural mechanization. These challenges pose a serious impediment to the growth of the industry and agriculture. The key challenges faced by the farm mechanization in India (Mehta and Pajnoo, 2013) are as follows.

1. The average farm size in India is small (1.16 ha) as compared to the European Union (14 ha) and the United States (170 ha). Therefore, there will be little mechanization unless machines appropriate for small holdings are made available. Due to small size of land holdings, it is difficult for the farmers to own machinery. As a result, the benefits of mechanization are enjoyed by only a section of the farmers who have large farm holdings.

2. Mechanizing small and non-contiguous group of small farms is against 'economies of scale' especially for operations like land preparation and harvesting. With continued shrinkage in average farm size, more farms will fall into the adverse category thereby making individual ownership of agricultural machinery progressively more uneconomical.

3. The major constraint of increasing agricultural production and productivity is the inadequacy of farm power and machinery with the farmers. The average farm power availability needs to be increased to minimum 2.5 kW/ha to assure timeliness and quality in field operations, undertake heavy field operations like sub-soiling, chiseling, deep ploughing and summer ploughing.

4. Matching equipment for tractors, power tillers and other prime movers are either not available or farmers make inappropriate selection in the absence of proper guidance, resulting in fuel wastage and high cost of production.

5. Almost 90 % of tractors are sold in India with the assistance of some financial institution. Sale of farm machinery is driven by factors like financial support, limit of funding (in terms of percentage of the cost), funding/financing institution and the applicant's profile (deciding the credibility of the loanee).

6. The high cost and energy efficient farm machinery are capital intensive and majority of Indian farmers are not able to acquire these assets due to shortage of capital with them.

7. Cropping pattern decides the extent of mechanization required for timely operations and achieving optimum results. The scope of mechanization increases with intensive cropping pattern. Price realized by the crop is also an important factor, as it indicates the cash in hand for the farmer.

8. Hill agriculture, which covers about 20 % of cultivated land, has little access to mechanization. This situation has to be improved by developing and promoting package of technology for mechanization of hill agriculture to achieve higher productivity.

9. There are wide technology gaps in meeting the needs of various cropping systems and regions. The Indian farmers have limited access to the latest equipment and technology. Further, there is little feedback from the farmers for product improvement and product acceptance.

10. The quality of farm implements and machinery manufactured by small scale industries in the country is generally not of desired standard resulting in poor-quality work, longer down time, low output and high operational cost. The quality of equipment has to be improved.

11. The after sales service of farm machinery is the other concern in India as the majority of farmers are cost conscious. There are inadequate service centers for proper upkeep of the machinery.

Strategy for Mechanization of Indian Agriculture

Agricultural mechanization should contribute to sustainable increase in productivity and cropping intensity so that the planned growth rates in agricultural production are achieved. Mechanization is capital intensive and substantial sums have been invested in our country. In the absence of good planning and direction, investment on mechanization may not yield the expected results. India adopts a policy of selective mechanization under diverse conditions, which makes the agricultural mechanization a challenging task. An appropriate mechanization technology suiting to the needs of the farmers is required to be adopted. This may be achieved by following a few points as mentioned below.

1. The widely fragmented and scattered land holdings in many parts of the country need to be consolidated (virtual or real) to give access for their owners to the benefits of agricultural mechanization.

2. There is a need to have more interaction among the farmers, research and development workers, departments of agriculture and industry to make farm machinery research and development base stronger.

3. To achieve higher production levels, the quality of operations like seedbed preparation, sowing, application of fertilizer, chemicals and irrigation water, weeding, harvesting and threshing will have to be improved by using precision and efficient equipment.

4. The rice transplanting operation can be mechanised by introduction of self-propelled walking type rice transplanters on small and medium land holdings. The riding type rice transplanter may be introduced on large size land holdings on custom hiring basis (Mehta and Pajnoo, 2013).

5. The benefits of agricultural mechanization should be extended to all categories of farmers with due consideration to small and marginal farmers, to all cropping systems including horticultural crops and to all regions of the country especially the rainfed areas.

6. There is a need to innovate custom service or a rental model by institutionalization for high cost farm machinery such as combine harvester, sugarcane harvester, potato combine, paddy transplanter, laser guided land leveller, rotavator etc. and can be adopted by private players or State or Central Organizations in major production hubs.

7. The high capacity rice combines may be introduced to paddy growing areas on custom hiring basis. It will help in timely harvesting and better yield of paddy crop.

8. Medium and large scale farmers may be provided with Govt. subsidies to encourage them to buy and to apply advanced medium and high size machinery such as cotton picker, rice transplanter, sugarcane harvester and combine harvester on their fields (Mehta and Pajnoo, 2013).

9. The farm machinery bank may be established for machines being manufactured elsewhere in the country and supply to users/farmers on custom hiring mode.

10. Provision may be made for special credit support at lower interest rates to rural individuals, venturing into entrepreneurial use of farm machinery through custom hiring (Mehta and Pajnoo, 2013).

11. Manufacturing units that are set-up in areas with lower mechanization needs to be supported by extending tax and duty sops. This would result in easier reach of the equipment to farmers in those areas (Mehta and Pajnoo, 2013).

12. There is a need for quality manufacturing and after sales support for reliability of farm machinery. This may be achieved by streamlining of testing procedure, training of engineers and conducting testing of farm equipment for standardisation and quality control in farm equipment manufacturing.

13. There is a need for strengthening training programmes at various levels and for different categories of people on operation, repair and maintenance of agricultural machinery, tractors, power tillers, rice transplanters, combines etc. and for transfer of technology.

14. The quality of life and work environment of farmers/farm women need to be improved. Their work involves considerable drudgery and discomfort. Proper ergonomic designs of agricultural equipment, incorporating latest safety measures and 'comfort features' should be made available.

Conclusions

The production and productivity in Indian agriculture cannot be enhanced by primitive and traditional practices of farming. The average farm size in India is 1.16 ha and mechanizing small and non-contiguous group of small farms is against ‘economies of scale’ especially for operations like land preparation and harvesting. With continued shrinkage in average farm size, more farms will fall into the adverse category thereby making individual ownership of agricultural machinery progressively more uneconomical.

The combine share of agricultural workers and draught animals in total farm power availability in India reduced from 60.8 % in 1971-72 to 10.1 % in 2012-13. The average farm power availability needs to be increased from 1.84 to 2.5 kW/ha by 2025 to assure timeliness and quality in field operations. Therefore, India adopts a policy of selective mechanization under diverse conditions, which makes the agricultural mechanization a challenging task.

The widely fragmented and scattered land holdings in many parts of the country need to be consolidated to give access for their owners to the benefits of agricultural mechanization. The small farms can be mechanised by use of improved manual tools and animal drawn farm equipment on individual ownership basis or high capacity farm machinery on custom hiring basis. Medium and large scale farmers may be provided with Govt. subsidies to encourage them to buy and to apply advanced medium and high capacity machinery such as cotton picker, rice transplanter, sugarcane harvester and combine harvester on their fields. The farm machinery bank may be established in low farm power availability region for machines being manufactured elsewhere in the country. There is a need to innovate custom service or a rental model by institutionalization for high cost farm machinery and can be adopted by private players or Governmental organizations in major production hubs. The quality manufacturing and after sales support for farm machinery are also needed for reliability of farm machinery.

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Human Factors Intervention and Design Improvement of Manual Single Row Conoweeder for Gender Neutrality in Lowland Rice

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Abstract

The original IRRI manual single-row cono-weeder that is widely used in Indian lowland rice fields since eighties was modified by giving due ergonomic consideration in the investigation and comparison was made with the measured parameters to ascertain the improved comfort of the operator. The ergonomical evaluation of three makes in lowland rice with twelve female subjects reveals that the operation of all weeders is graded as 'heavy' with respect to energy expenditure. Since the mean oxygen consumption rate of female subjects as percentage of VO_2 max are above the acceptable work load (W_1: 72.0 %, W_2: 76.2 %, W_3: 82.8 %), rest pause of 7.4, 10.5, and 12.9 min respectively for every 45 min of operation was recommended to overcome the problem of fatigue. Discomfort rating was on par with all weeders and they are above the limit of moderate discomfort. In view of body part discomfort score of the subjects, W_1 registered the lowest discomfort. Force requirement in push and pull mode was 36.4, 35.1 N with W_1, 37.5, 37.0 N with W_2, and 43.3, 43.1 N with W_3 respectively. The adoption of weeders with improved ergonomic design features in W_1 and W_2 enhanced the comfort of the subjects with respect to prominent ergonomic parameters. It was concluded that the human factors engineering interventions that have been given to the single-row manual cono-weeders in the study have proved its superiority in lowland rice.

Introduction

Weed control is one of the most expensive operations in crop production. Manual weeders are found widely used in low land rice as they are found acceptability due to low cost. However manual weeders need human effort to operate. The physiological cost of work depends on the heart rate, oxygen consumption rate, but the severity of work not only depends upon the energy expenditure rate but also on the discomfort rate in different body parts (Kroemer and Gajendran, 2000). Many researchers have revealed that cono-weeder operation is the highest energy demanding operation compared to other rice faming machinery activities (Vidhu, 2000). Moreover it is required to be operated many times for obtaining weed free yield (Johnson *et al*., 2004).

Human labour is the single costliest input in farming operations contributing to major part of the total cost of the cultivation. Many farm implements and machinery of the country hitherto have not been ergonomically developed in the country; manual cono-weeders are also not exceptional. With increasing awareness for ergonomics and safety in agricultural field operations, human factors engineering inventions are needed for improving the manually operated tools and equipment.

An experiment was conducted with manual single-row cono-weeders to identify the improvements required for the fit between physical demands of the tools and the worker who perform the task. The investigation quantified the drudgery involved in weeding operations with the cono weeders selected systematically in all aspects which would greatly help the researchers and manufacturers to appropriately design simple and labour effective gadgets considering ergonomics requirements. Such design would not only minimize drudgery of the farm labours but also increase productivity at reduced energy expenditure levels.

The paper deals the human factor engineering interventions made by Central Institute of Agricultural Engineering, Industrial Extension Project Centre, Coimbatore, India on the design of two models of manual single-row cono-weeders and the effect of these intervention on performance and drudgery reduction.

Materials and Methods

Working Principles of Manual Single-Row Cono-Weeder

Cono-weeder uproots and buries weeds in between standing rows of rice crop in wetlands. Two truncated rollers one behind other are fitted at the bottom of the long handle. The conical rollers have serrated blades on the periphery. A float provided in the front portion prevents the unit from sinking into the puddled soil. The cono weeder can also be used for trampling the green manure crop in addition to weeding operation. It disturbs the topsoil and increases the aeration. The cono-weeder operation is disturbing the soil around rhizosphere region thereby providing adequate aeration the soil. It is allowing roots to respire and pruning of older roots, thereby freshly formed roots are white in colour. Top soil is continuously kept muddy and nearer to colloidal and hence less irrigation water requirement. Soil is heaped and earthed up covering fewer lower nodes near the tillering zone of the hills leaving ample scope for increasing the phyllocrons. Crown of all is that partial pruning of roots induce newer root proliferation. This helps in better and efficient absorption of nutrients and translocation towards its sink (produce).

Ergonomics Interventions

The IRRI manual single-row cono-weeder introduced in India through the Central Institute of Agricultural Engineering, Industrial Extension Project Centre, Coimbatore during late eighties was further studied on human factors engineering aspects and two leading collaborative manufacturers were motivated to take up the improved cono-weeders for mass production after incorporating ergonomics components designed by CIAE. The ergonomic improvements incorporated includes,

1. improving smoothness of the cone by adopting improved production technologies that would eliminate welding on the outer surface of the cones.

2. increasing the length of the handle from 1200 mm to 1400 mm in both the improvised mokes that ensure the indefatigable works by women workers

3. reducing weight of the unit from the original weight of 7.5 kg to 5.5 kg (W_1) and 6.1 kg (W_2) through modern production methods in view of increasing field capacity and reducing fatigue as well.

Sample Selection and Description

About twenty thousand units were manufactured commercially on these two makes in the past four years. Two samples of cono-weeders were selected from each make and the effect of ergonomics intervention on these models was evaluated in the field. The specifications of the cono-weeders are given in **Table 1** and the descriptions of the weeders after the ergonomical intervention are given below.

Weeder W_1: The overall weight of the unit has been reduced from the original weight of 7.5 kg to 5.5 kg and this lighter weight enhances ease of operation with reduced drudgery. A 32 mm dia pipe is provided as central axis for ease of operation by replacing the existing 16 mm bolt. The elimination of heavy bolts helped in considerable weight reduction as well as easier rolling of cones in puddled soil. Generally more welding is required in mild steel sheet works. In existing models, cone and leaf are manufactured separately and joined together by lengthy welding process, due to which number of welding spots are seen on the outer surface. But in improved metallic cono weeder, there is no separate cone. However, six numbers of segments with leaf are joined together just like cone. Six leaves are attached firmly by spot welding inside the cones. This method reduces lot of welding cost and weight of cones, and also eliminates the welding spots on the outer surface. The smooth outer surface (of cones) maintained by this method enhances less force requirement due to low resistance. The telescopic handle facilitates to adjust height and length of the handle. In view of improving rigidity, the float is attached through square pipe with handle, due to which the force loss is reduced considerably. Hence force requirement to operate the tool is reduced.

Weeder W_2: This has long handle, plastic moulded cones, and float. The plastic cones made of Polypropylene copolymer (PPCP) can be directly fitted in the bent pipe with M-12 nut and the bent pipes are welded at the float pipe. The cones are made by using the injection moulding process where molten PPCP is injected at high pressure into a mould, which is the inverse of the desired shape. Straight blade and serrated lugs made of mild steel

Table 1 Specifications of units Parameters

Parameters	W_1	W_2	W_3
Overall dimension (l × b × h), mm	2,140 × 500 × 1,070	2,000 × 520 × 1,000	1,800 × 500 × 1,000
No. of rows	1	1	1
Weight, kg	5.5	6.1	7.5
Working width, mm	140-160	170 -190	100
Number of Cones	2 (metallic)	2 (plastic)	2 (metallic)
Height of handle from ground, mm	1,070	1,000	1,000
Length of handle, mm	1,400	1,400	1,200
No. of blades in weeding cone	Straight blade - 6; Serrated blade - 6	Straight blade - 6; Serrated blade - 6	Straight blade - 6; Serrated blade - 6
Blade thickness, mm	1.6, 2.0	2.0	2.0
Width of handle, mm	500	520	500
Size of float (L × B × H), mm	330 × 120 × 70	350 × 120 × 65	320 × 120 × 70
Float angle (O)	20	21	20
Handle grip diameter, mm	20	20	20

sheet of 2 mm thickness are inserted into the mould die before starting of moulding process, which would tightly hold the lugs. The smooth outer surface of the two cones produced by this injection moulding method enhances less force requirement due to low resistance. The telescopic handle facilitates to adjust the height and length of the handle. The overall weight of the unit has been reduced from the original weight of 7.5 kg to 6.1 kg and this lighter weight enhances ease of operation with reduced drudgery.

Weeder W_3: Two truncated rollers one behind other are fitted at the bottom of the long handle. A bolt of 16 mm dia is provided to act as central axis. The conical rollers have serrated blades on the periphery. A float provided in the front portion prevents uniform sinking into puddled soil. The handle is made of mild steel tube. The weeders W_1, W_2 and W_3 are shown in **Fig. 1**.

As weeding is carried out by women workers traditionally and cono-weeder was designed gender friendly, twelve women workers were selected for the study. Since maximum strength and power can be expected from the age group of 25 to 35 years (Gite and Singh, 1997) it was ensure to select the subjects in medium age group. Bio-clinical analysis of the blood of the selected workers was carried out for blood sugar, blood urea, hemoglobin, and serum cholesterol for identifying hypertension ailments and hypothyroid diseases and urine analysis for diabetes. It was also ensured that they are free from respiratory, cardiac, and other ailments. The selected subjects were standardized and calibrated with the help of a bicycle-ergometer to compute the VO_2 max. Anthropometrical data and other basic details of the subjects selected are presented in **Table 2**.

Performance Evaluation

The field evaluation of the two models of manual single-row cono weeders those underwent to ergonomics intervention viz, W_1, W_2, and the IRRI manual single-row cono-weeder (W_3) was conducted at lowland paddy fields in the standing crop of ADT 43 variety at Agricultural Research Station, Tamil Nadu Agricultural University, Bhavanisagar, Tamil Nadu, India in 2011. During the experiment, observations on effective field capacity, weeding index, plant damage, and performance index were determined. Weeding index and performance index were measured by following formulae.

Weeding index, $WI = (N_1 - N_2) / N_1$

where,

N_1 = number of weeds per unit area before weeding

N_1 = number of weeds per unit area after weeding

Performance index, PI = fexqxWI/p

Where,

Fig. 2 Ergonomics evaluation of cono-weeders with women subjects

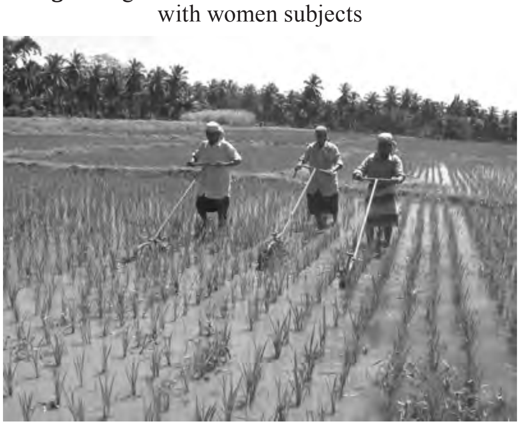


Fig. 1 Cono-weeders under study Selection of subjects

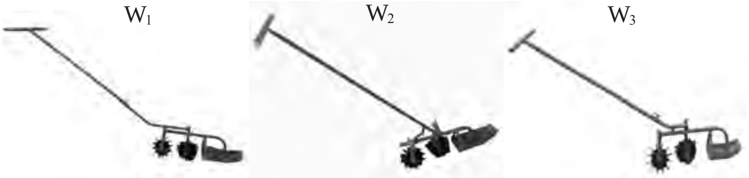


Table 2 Basic particulars of subjects

Particulars	Subject											
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}
Age, year	34	29	26	28	27	32	27	28	28	34	31	26
Stature, cm	160	159	158	160	164	169	170	162	165	162	160	159
Weight, kg	66	54	56	54	65	60	65	62	72	66	63	63
Heart raterest, beat/min	71	73	72	70	71	73	73	71	75	72	71	71
Heart rate max, beat/min	196	198	202	184	186	190	200	182	192	203	197	194
Blood pressure, mmHg	119/ 79	122/ 82	118/ 80	122/ 80	120/ 80	118/ 78	118/ 79	120/ 80	122/ 81	119/ 78	120/ 80	121/ 80
BMR, kCal/day	1,240	1,128	1,295	1,220	1,580	1,461	1,486	1,384	1,520	1,384	1,208	1,113
VO_2 rest, l/min	0.24	0.19	0.23	0.21	0.17	0.20	0.21	0.22	0.19	0.18	0.24	0.17
VO_2 max, l/min	2.04	1.92	1.97	2.21	2.14	2.18	2.02	2.31	2.09	1.91	2.08	2.18
Breath rate, No./min	15	14	17	16	17	14	16	17	16	18	14	15
Experience, year	5	5	6	7	5	6	8	6	7	9	5	7

f_e = effective field capacity

q = 100 − percentage plant damage

p= power output of the worker (0.1 hp) (Anon, 1981 and Rodahl, 1989)

Ergonomical Evaluation

Ergonomical evaluation was carried out (**Fig. 2**) with twelve female subjects for assessing their suitability in terms 1) Heart rate and oxygen consumption rate, 2) Energy cost of operation, 3) Acceptable work load (AWL), 4) Limit of continuous performance (LCP), 5) Over all discomfort rating (ODR), and 6) Body part discomfort score (BPDS).

Results and Discussion

Performance Evaluation

The highest effective field capacity was found to be with W_1 (293.5 m^2/h) followed by W_2 (265.0) and W_3 (190.0). It was found non-significant among the subjects (replications). There was no significant variation of effective field capacity among W_1 and W_2. However there was significant variation ($p < 0.05$) of effective field capacity between W_1 and W_3 as well as W_2 and W_3. This may be due the fact that the performance of the weeders viz., W_1 and W_2 those underwent for ergonomics intervention have performed well with respect to effective field capacity. Plant damage was found to be 5.3, 5.9, and 6.1 percent with W_1, W_2, and W_3 respectively with non-significant variation both among weeders and subjects.

The highest weeding index was recorded in case of W_1 (82.5 %) followed by W_2 (81.1 %) and W_3 (75.2 %) which indicates non-significant variation between W_1 and W_2. However the weeding index with W_3 was significantly lower than W_1 and W_2. The field capacity was observed to be lowest in the case of W_3 due the fact that the force requirement is highest (43.3 ± 3.38 N) with W_3. The plant damage with W_3 was also lowest as the effective field capacity (190.0 ± 13.02 m^2/h) and weeding index were lesser while pushing force, plant damage were higher comparatively. The performance index was on par with W_1 and W_2, while W_3 registered least performance index of 1358.1 ± 106.8 as presented in **Table 3**. This shows that the improved cono-weeders gave better performance.

Fig. 3 Heart rate response of subjects

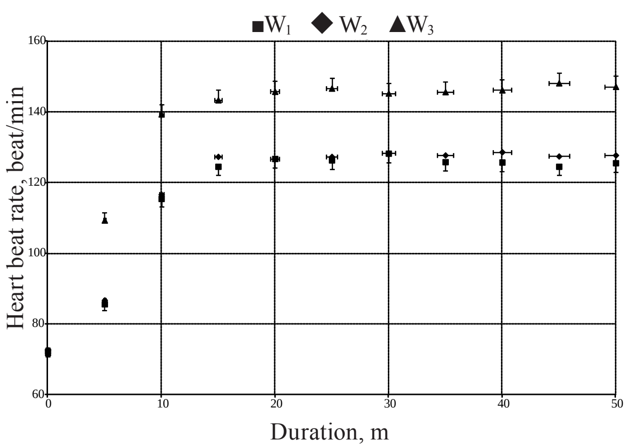
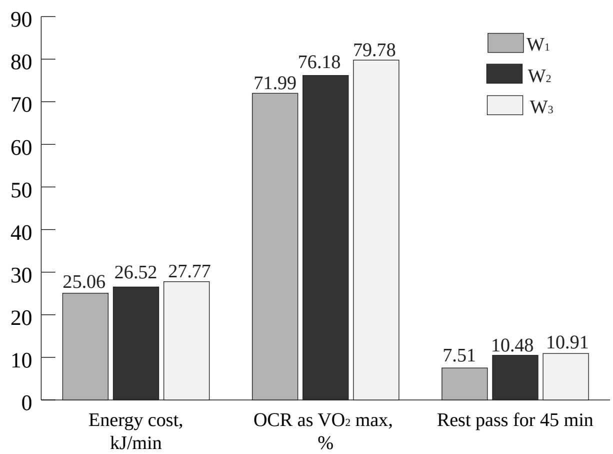


Fig. 4 Physiological workload with cono-weeders



Ergonomical Evaluation

Ergonomical evaluation of the selected cono-weeders for paddy was carried out in terms of the ergonomics parameters as explained in material and methods. A comparison of the weeders was made with the measured parameters to ascertain the improved comfort of the operator and the results are furnished below.

1. Physiological response: The physiological load of weeders under investigation with the female subjects during the field operation is furnished in **Table 3**. The mean values of heart rate (**Fig. 3**) and oxygen consumption of the three weeder operation reveals that the operation of all weeders is graded as 'heavy' according to Sen classification for Indian workers (Sen, 1969). The average oxygen consumption rate of female subjects as percentage of VO_2 max for the weeding operation with cono-weeders W_1, W_2, and W_3 were 71.99, 76.18, and 79.78 percent

Table 3 Field performance of weeders

Weeder	Subject	Effective field capacity, m²/h	Weeding index, %	Pushing force, N	Plant damage, %	Performance index
W_1	S_1	295	86.1	34.8	5.8	2,392.6
	S_2	294	84.6	37.2	5.4	2,352.9
	S_3	276	79.6	34.2	5.6	2,073.9
	S_4	285	81.2	38.1	4.9	2,200.8
	S_5	304	79.6	37.6	4.5	2,310.9
	S_6	309	79.3	34.7	4.6	2,337.7
	S_7	289	80.6	32.9	5.8	2,194.2
	S_8	294	84.5	35.6	4.9	2,362.6
	S_9	279	86.4	37.4	6.4	2,256.3
	S_{10}	299	86.1	39	5.8	2,425.1
	S_{11}	307	84.9	36.4	4.8	2,481.3
	S_{12}	292	79.8	38.4	4.6	2,223.0
	Mean	293.5	82.5	36.4	5.3	2,301.0
	SD	9.90	2.80	1.82	0.59	110.0
W_2	S_1	264	80.1	36.5	5.8	1,992.0
	S_2	269	84.0	38.1	5.6	2,133.1
	S_3	280	86.1	34.6	9.4	2,184.2
	S_4	278	79.0	37.5	5.1	2,084.2
	S_5	269	78.7	36.9	4.6	2,019.6
	S_6	275	80.7	35.6	5.0	2,108.3
	S_7	256	78.2	37.2	4.9	1,903.8
	S_8	280	76.4	38.5	4.8	2,036.5
	S_9	249	84.6	37.9	8.7	1,923.3
	S_{10}	254	82.6	36.4	5.9	1,974.3
	S_{11}	259	84.6	39.4	5.7	2,066.2
	S_{12}	257	79.8	40.9	5.4	1,940.1
	Mean	265.0	81.1	37.5	5.9	2,031.9
	SD	10.42	2.94	1.62	1.47	84.1
W_3	S_1	203	72.3	42.5	5.9	1,381.1
	S_2	196	74.0	39.8	4.8	1,380.8
	S_3	202	72.6	36.9	7.6	1,355.1
	S_4	216	79.0	42.6	8.6	1,559.6
	S_5	189	72.8	43.7	4.8	1,309.9
	S_6	183	81.6	44.5	5.9	1,405.2
	S_7	170	80.5	46.8	7.6	1,264.5
	S_8	181	79.4	39.9	8.1	1,320.7
	S_9	179	74.6	48.2	5.4	1,263.2
	S_{10}	204	80.4	46.9	4.9	1,559.8
	S_{11}	190	71.9	47.1	5.6	1,289.6
	S_{12}	177	70.8	40.8	4.5	1,196.8
	Mean	190.0	75.2	43.3	6.1	1,358.1
	SD	13.02	3.83	3.38	1.38	106.8

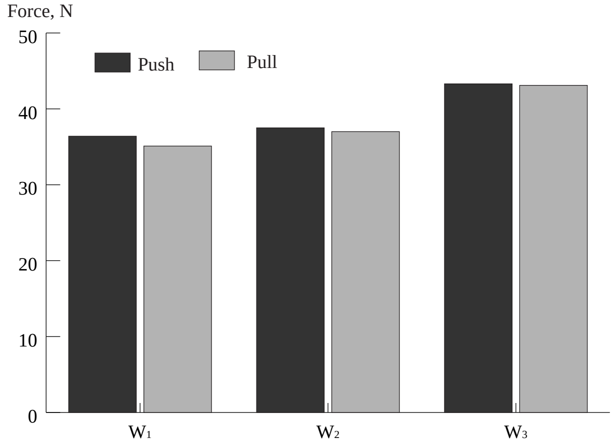
respectively which denote all these three are above the acceptable work load of Indian female workers i.e. 35 % VO_2 max according to Saha *et al*. (1979). Hence rest pause of 7.51, 10.48, and 10.91 min for every 45 min of operation with weeders W_1, W_2, and W_3 is recommended to overcome the problem of fatigue (**Fig. 4**). The discomfort rating was on par with all weeders evaluated and they are above the limit of moderate discomfort. In view of body part discomfort score of the subjects, it is revealed from the table that weeder W_1 registered the least discomfort amongst all followed by W_2.

2. Force measurement: The force measurement trials were conducted with the cono- weeders using load-cells both on push and pull mode. The force requirement was 36.4, 35.1 N with W_1, 37.5, 37.0 N with W_2, and 43.3, 43.1 N with W_3 for push and pull respectively as depicted in **Fig. 5**. It is observed that the force required for both push and pull is on par for all the three weeders while the force required on push and pull mode is the least with W_1 followed by W_2. In view of improving rigidity, the float is attached

Table 4 Physiological response of female subjects

Weeder	Subject	Heart rate, beat/ min	VO_2, l/min	ODR Score	Body Part Discomfort Score	Energy cost, kJ/ min	OCR as VO_2 max, %	Energy Grade	*Rest pause, min
W_1	S_1	128	1.23	5.3	24.5	23.8	71.3	Heavy	7.3
	S_2	124	1.04	5.4	24.3	26.2	73.5	Heavy	7.6
	S_3	126	1.16	5.9	24.6	24.1	72.6	Heavy	7.5
	S_4	128	1.23	5.6	23.1	24.6	73.1	Heavy	6.9
	S_5	128	1.36	5.4	25.0	24.5	73.4	Heavy	7.8
	S_6	119	1.18	5.1	25.1	25.4	72.6	Heavy	7.6
	S_7	129	1.24	5.9	22.9	24.9	69.3	Heavy	7.1
	S_8	128	1.33	5.8	25.6	26.2	71.2	Heavy	7.9
	S_9	121	1.05	5.0	23.4	26.2	69.1	Heavy	7.6
	S_{10}	117	1.18	5.1	22.1	24.9	72.9	Heavy	7.5
	S_{11}	124	1.19	4.9	24.6	26.7	72.9	Heavy	7.2
	S_{12}	129	1.26	5.4	21.9	23.8	72.4	Heavy	7.3
	Mean	125.1	1.21	5.40	23.93	25.1	72.0	Heavy	7.4
W_2	S_1	132	1.27	5.6	28.1	26.4	77.6	Heavy	11.2
	S_2	135	1.29	5.7	26.5	26.8	75.9	Heavy	10.8
	S_3	129	1.18	5.3	23.9	27.4	76.4	Heavy	10.9
	S_4	127	1.27	5.6	24.8	24.9	76.3	Heavy	10.3
	S_5	130	1.16	5.4	26.4	26.4	75.8	Heavy	10.8
	S_6	128	1.28	5.6	28.6	26.1	74.9	Heavy	9.9
	S_7	127	1.11	5.2	24.9	25.8	76.5	Heavy	10.4
	S_8	126	1.31	4.9	29.4	25.0	78.9	Heavy	10.6
	S_9	131	1.38	5.9	30.5	25.6	76.4	Heavy	10.4
	S_{10}	129	1.30	5.1	27.1	27.8	75.1	Heavy	10.1
	S_{11}	132	1.40	5.8	23.1	27.3	74.8	Heavy	10.3
	S_{12}	120	1.30	5.9	22.8	29.0	75.9	Heavy	10.6
	Mean	128.8	1.27	5.50	26.34	26.5	76.2	Heavy	10.5
W_3	S_1	141	1.36	5.6	43.5	26.4	83.5	Heavy	12.8
	S_2	142	1.19	6.3	46.2	27.4	83.6	Heavy	13.2
	S_3	136	1.21	6.4	38.5	29.0	83.1	Heavy	12.8
	S_4	142	1.27	6.2	39.5	28.7	82.8	Heavy	13.5
	S_5	130	1.09	6.0	43.1	26.8	83.4	Heavy	12.4
	S_6	146	1.38	5.8	40.5	26.4	83.0	Heavy	12.9
	S_7	156	1.43	5.9	46.3	29.4	83.4	Heavy	12.6
	S_8	145	1.37	5.6	39.1	28.9	79.6	Heavy	13.1
	S_9	150	1.42	5.4	38.6	29.8	82.1	Heavy	12.8
	S_{10}	140	1.51	5.9	40.6	26.7	83.4	Heavy	13.4
	S_{11}	151	1.32	5.5	40	27.9	82.6	Heavy	12.4
	S_{12}	162	1.45	6.2	39.4	26.1	83.4	Heavy	12.9
	Mean	145.1	1.33	5.90	41.28	27.8	82.8	Heavy	12.9

Fig. 5 Force requirement for cono-weeder operation



through square pipe with the handle, due to which the loss on push-pull forces have reduced considerably; and hence force requirement to operate the tool is also reduced with both W_1 and W_2.

Conclusions

The use of manual cono-weeders with improved ergonomics design features enhanced the comfort of the subjects with considerable reduction in heartbeat, oxygen consumption, energy expenditure, acceptable work load, limit of continuous performance, overall discomfort rating, body part discomfort rating, and force requirement. In this way, it is concluded that the human factors engineering interventions that have been provided in the study have proved their superiority in low land rice with the single-row cono-weeders to enhance gender neutrality.

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■■

NEWS

Congratulations!!! **Dr. Kushwaha wins Bekker-Reece-Radforth Award of ISTVS**

Dr. Radhey Lal Kushwaha, AMA's Editorial Consultant, received the highest award "Bekker-Reece-Radforth Award" at the 18th International Conference of ISTVS (International Society for Terrain-Vehicle Systems) held at Seoul National University, Seoul, Korea, September 22-25, 2014. The ISTVS was founded in 1962 at the request of the General Assembly of the First International Conference on the Mechanics of Soil-Vehicle Systems held in Turin, Italy to acquire and advance knowledge of the mechanics of terrain-vehicle systems and machinery interacting with soils in all environments. The award, "Bekker-Reece-Radforth Award" is to honour ISTVS members who has worked for at least three consecutive years and has accomplished a) outstanding research achievements that have led to major improvements in engineering practice in off-road vehicle, soil engaging equipment or related industries, b) exceptional engineering achievements in product innovation or product development and design in off-road vehicle, soil engaging equipment or related industries. Dr. Kushwaha was hourned for a) his contributions to terramechanics education and outreach in Canada and in India, b) long publication record in the field of terramechanics and c) multiple patents and provisional patents for agricultural related sensors, mechanical and bio-composite devices. During this International Conference, Dr. Kushwaha was also elected as the Fellow of the ISTVS. At present, he is professor emeritus in the Department of Chemical and Biological Engineering at University of Saskatchewan, Canada, and has been working actively for agricultural mechanization.

■■

Energy Budgeting of Sustainable Rice Based Cropping Systems in Sub Tropical India

by
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Abstract

The field investigations were carried out for energy dynamics in terms of various input used and outputs harvested under rice (*Oryza satva L.*) based cropping systems at the research farm of Project Directorate for Farming Systems Research, Modipuram, Meerut, India during 2003 to 2007. The experiments were conducted with five rice planting methods, viz. direct seeding; 1) dry bed, drum seeding 2) wet bed, mechanical transplanting 3) puddled, mechanical transplanting 4) unpuddled and manual transplanting 5) puddled and three cropping systems involving rice (*Oryza satva L.*)-wheat (*Triticum aestivum L. emend. Fiori. Paol.*), rice-chickpea (*Cicer arietinum L.*) and rice-mustard (*Brassica Juncia L. czernj & coss.*) crops in randomized block design replicated three times. The results revealed that the input energy consumed was 40, 27, 14 and 7.7 percent in fertilizer, diesel fuel for irrigation, machineries, and labour of total energy used, respectively, for crop production in rice-wheat system. The comparison of different cropping systems shows that rice-chickpea consumed least input energy (i.e. 30,698 to 35,046 MJ/ha) followed by rice-mustard (varied from 36,195 to 40,543 MJ/ha) and rice-wheat (varied from 39,984 to 44,332 MJ/ha). System wise energy analysis indicated that the highest input energy (44,332 MJ/ha) was consumed in manually transplanted (puddled) followed by mechanically transplanted-puddled (43,686 MJ/ha) while lowest was mechanically transplanted-unpuddled (39,984 MJ/ha), direct seeded-dry bed (42,027 MJ/ha) and drum seeded-wet bed (42,197 MJ/ha) in rice-wheat system. The output energy was highest in drum seeded (212,798 MJ/ha) closely followed by direct seeded (211,350 MJ/ha) and lowest was manually transplanted in puddled (193,916 MJ/ha) which is statistically at par. The net return energy of the system was found to be high in drum seeded (170,595 MJ/ha) followed by direct seeded (169,271 MJ/ha) and lowest was in manually transplanted in puddled (149,390 MJ/ha) which were non-significant. The direct and drum seeded required about 5 percent less input energy and gave 8 to 9 percent higher output energy as compared to manually transplanted in puddled field. Whereas, in case of mechanically transplanted (unpuddled), it required 10 percent less input energy and provided 6 percent higher output energy, however, in puddled condition mechanically transplanted required 1.5 percent less input energy and gave 3 percent higher output energy as compared to manually transplanted (puddled). Similar pattern of energy dynamics were also found in rice-chickpea and rice-mustard systems.

Keywords: Energy input, output and net return energy, MTR energy, rice based cropping systems

Introduction

There has always been a close connection between energy and agriculture. In the past three decades it has been seen that the dependency of agriculture on energy has increased particularly for fossil fuels. Efficient energy use is important for sustainable agricultural production as it reduces pollution and improves financial viability. Due to increase in population and longevity of life combined with limited supply of arable land, there has been a rise in energy inputs to maximize yields (Stout, 1990). Agriculture has a dual role to play that is both as a supplier and user of energy. Agriculture has key role to play in mitigating climate change by substituting bioenergy for fossil fuels (Omar, 2003; Venturi and Venturi, 2003). The energy in agricultural production is invested in various forms like mechanical, chemical fertilizers, pesticides, and herbicides and electrical (Chaudhary *et al.*, 2009). The amount of energy used in agricultural production, processing and distribution needs to be adequate in order to feed the rising population and to meet other social and economic goals. Sufficiency in energy and its effective and efficient use are prerequisites for improved agricultural production. It has been seen that crop yields and food supplies are directly linked to energy (Singh *et al.*, 2007). In developed countries, rise in crop yields were mainly attributed to rise in use of improved commercial energy inputs in addition to improved crop varieties (Lal *et al.*, 2003). Effective energy use in agriculture is one of the conditions for sustainable agricultural production (Chaudhary *et al.*, 2008), since it provides financial savings, fossil fuels preservation and air pollution reduction.

Agriculture uses large quantities of locally available non-commercial energy and commercial energy (Chaudhary *et al.*, 2006a). Efficient use of different energy forms helps to achieve increased production, productivity, profitability and competitiveness of agriculture sustainability in rural living (Chaudhary *et al.*, 2006b). Energy input-output relationships in cropping systems vary with crops being grown in sequence, by type of soils, nature of tillage operations for seedbed preparation, nature and amount of organic manure, chemical fertilizer, plant protection measures, harvesting and threshing operations and finally, the yield levels (Chaudhary *et al.*, 2009; Lal *et al.*, 2003; Chaudhary *et al.*, 2006a).

Lack of sufficient oil and the high price of oil products have forced some countries to be more and more energy efficient in all sectors, therefore, there is a need for the developing countries to invest on research for sustainable agriculture growth and proper energy use in developing countries , particularly in India. The vast experience in India shows rapid increase in production and productivity in agriculture due to the introduction of high yielding varieties seeds (HYV), use of fertilizers, use of energy intensive production, etc. The amount of energy used in agricultural production, processing and distribution would be significantly high in order to feed the expanding population and to meet other social and economic goals. Sufficient availability of the right energy at right time, its effective and efficient use is prerequisites for improved agricultural production. The increases in yields per hectare in the developed countries were as a result of commercial energy inputs, in addition to improved varieties (Faidley, 1992). The methodology to quantify energy consumption in agricultural production has been done by numerous studies by different researchers (Bridges and Smith 1979; Heslop and Bilanski 1989; Swanton *et al.* 1996; Vinten-Johansen *et al.* 1990; Zentner *et al.*, 1984). The irrigation consumed the maximum energy in the all farm operations for both paddy (81.9 %) and wheat (31.08 %) crops. The energy need for raising crop depends upon variety of factors out of which technology level and agro climatic factors are most important (Mittal *et al.*, 1992). It was suggested that steps should be initiated to rationalize the use of various forms of energy in wheat production so as to improve the efficiency of marginal, small and medium farms (Singh *et al.*, 2007).

The primary objectives of mechanization of crop production were to increase the yield or area under production. These cannot be done with the traditional energy input that is labour but it can be achieved by farm machinery, irrigation equipment, fertilizers, soil and water conservation practices, weed management practices, etc (Chaudhary *et al.*, 2008; Chaudhary *et al.*, 2006b). These inputs need enormous energy and there is a need to conserve it. Therefore, there is a need to go for energy analysis which will tell us whether production practices are economically viable and effective. Further energy analysis which will helps to make sound management and policy decision and also for conservation.

With the aim of increasing production, the energy-agriculture relationship is becoming more and more important, as it is only source to increasing the productivity and further solving the problems of food security. It has been that rice and wheat has started showing signs of production stagnation and decline in productivity. Further, the traditional method of low energy farming is being replaced by modern high input is one of the concerns and reasons for stagnation. The present paper aims to analyse the energy relationship with rice production.

The objective of study is to analyze the energy of different rice establishment methods and to compare energetic of three rice based cropping systems. The attempt is made to audit energy input, output and return energy of three rice based cropping systems data obtained from farm studies under tillage managements in rice crop. The information on energy utilization in different rice-based cropping systems is not readily available. Therefore, in order to identify energy efficient rice based cropping systems and for satisfactory energy output, the present study has been undertaken.

Materials and Methods

Location, Climate and Soil

The study has undertaken at Project Directorate for Farming Systems Research, Modipuram, Meerut, U.P. India for a period of 2003-04 to 2006-07. It is situated at 29º 4′ N latitude and 77º 46′ E longitude at an elevation of 237 m above mean sea level and soil was sandy loam in nature with semi-arid subtropical climate.

Experimental Detail

The tillage treatments for kharif (rainy or mansoon season-June-September) crop included in the experiments were:

T_1 = Direct seeding (2 harrow + 2 cultivator + 2 planking): dry bed

T_2 = Drum seeding (2 harrow + 2 cultivator + 2 planking): wet bed

T_3 = Mechanical transplanting (2harrow + 2cultivator + 2 planking +2passes of puddler): puddled

T_4 = Mechanical transplanting (2 harrow + 2 cultivator +2 planking): unpuddled

T_5 = Manual transplanting (2 harrow + 2 cultivator + 2 planking +2 passes of puddler): puddled

The implements used for tillage were harrow (14-disc offset harrow in 580 mm diameter of discs, working width of harrow 1,700 mm and weighing 400 kg), cultivator (9 tines spring loaded, 72 mm wide with a tine spacing 200 mm and weighing 220 kg & width 530 mm and working width 2,140 mm), puddler (rotary type 330 mm diameter and total weighing 300 kg) and wooden planker for leveling.

The land preparation was done in dry field condition as described in each treatments then puddling was performed in treatment T_3 and T_5. In the Kharif crop, the mechanical transplanting was performed by self propelled rice transplanter with dimension (L × W × H: 2410 × 2131 × 1300 cm) and weighing 320 kg. The drum seeder with dimension (L × W × H: 1425 × 750 × 670 mm) and weighing 16 kg was used for sowing 8 row of sprouted rice with spacing of 200 mm. It is operated by two man power in wet field condition. In the Rabi crop, chickpea and mustard were sown after one harrowing plus one cultivator followed by one planking, however, wheat sowing was done in no till conditions. The sowing of above crops were done through bross roller metering —multicrop seed drill with dimension (L × W × H: 1850 × 650 × 1450 mm and weighing 300 kg) using 9 tines of inverted —T type furrow opener. with spacing of 200, 450 and 300 mm spacing for wheat, mustard and chickpea, respectively. Plantation of these crops were random in sequence of rice-wheat, rice-chickpea and rice-mustard crop in the study area.

Crop Management

The five rice planting methods were carried out random in sequence of rice-wheat, rice-chickpea and rice-mustard in randomized block design replicated three times. The dimensions of individual plots were 33 m × 4 m for rice and 10 m × 4 m for wheat, chickpea and mustard crop. The rice (cv. PHB 71) was sown at 20 cm apart with seeding rate @ 40 kg/ha. Crop cultivars used were PBW 243 of wheat, avrodhi of chickpea and varuna of mustard were sown 100, 75 and 6 kg seed rate/ha, respectively. The fertilizer doze for rice was 150 : 60 : 60 (N : P : K) kg/ha and 5.5 (Zn) kg /ha, for wheat and mustard it was 120 : 60 : 60 (N : P : K) except chickpea where 20 (N) kg/ha was applied along with P and K. Full dose of P and K were applied at time of land preparation by broadcasting. Nitrogen was applied in four equal splits in rice, three splits in wheat and mustard and single dose in chickpea crop. All the crops were grown under assured irrigated conditions, seeding of rice were done in direct drilling through zero till drill and drum seeder and the transplanting were done by mechanical transplanter and manual. Weedy rarely formed a problem in the upland rice after application of pendimethalin 35 EC at the rate of 1.25 kg a.i./ha in direct and drum seeded rice and butachlor 50 EC at rate of 1.5 kg a.i./ha as pre-emergence herbicide applied after 3 days of transplanting, followed by one hand weeding 30 days after sowing in all plots. Isoproturon was sprayed 35 days after sowing at the rate of 1.25 kg a.i./ha in all plots to control weeds in wheat.

Energy Budgeting

Energy inputs such as labour, machinery, irrigation, diesel fuel, chemical fertilizers, pesticides, consumption of electricity, etc were taken into consideration. In terms of outputs, rice, wheat, chickpea and mustard yields were used to estimate the energy and the unit used was mega joule (MJ). The energy inputs of each cropping system were evaluated. Energy coefficients for each process in the cropping system were taken from the literature. Different methods were used to calculate the energy used by different machinery, pesticides, fertilizers, yield energy outputs, etc which were given below.

Human Labour Energy

It is reported (Doering, 1980) that 68 percent of human energy is consumed for 8 hours of work per day, 21 percent for 6 hours of other activities, and 11 percent for 10 hours of rest. In Indian condition, 1.96 and 1.57 MJ/person-h energy coefficients from adult male and woman were used to obtain the human energy from average body weight, age and daily activities, a human labour (Gopalan *et al.*, 1978; Binning *et al.*, 1983). The following formula was used to calculate human energy input.

$$E_m = C_e N_m T_m M_J \quad \text{(1)}$$

Where,

C_e = 1.96 and 1.57 MJ/person-h energy coefficients from adult male and woman

N_m = Number of labour spent on a farm activity

T_m = Useful time spent by a labour on a farm activity, h

The total manual labour was recorded in each operation with working hours which was converted in man-hour. All other factors affecting manual energy were neglected.

Irrigation energy

In the experiment, the 7-12 HP diesel engine coupled to a centrifugal water pump to raise water from underground sources for irrigation of crop production was used. Diesel consumption in pump was recorded during each irrigation as per volume of water for every crop. Hence, for each crop irrigation, the diesel fuel was used to calculate the input energy. In this paper, the irrigation energy input was computed according to the formula used for fuel energy calculation.

Fuel energy

The majority of farm operations such as tilling, sowing, threshing and winnowing, etc were performed by diesel operated tractor in different crop production. Mechanical energy input was evaluated by quantifying the amount of diesel fuel consumed during various operations (Omar, 2003). The total time spent was also recorded. The operation wise input energy calculations were performed form diesel fuel.

The density of petroleum diesel is about 0.85 kg/l (7.09 lb/gal). When burned, diesel typically releases approximately 38.6 MJ/l (Safa and Tabatabaeefar, 2002). However, (Pimentel, 1976) suggests a higher diesel energy coefficient of 47.78 MJ/l (Esengun *et al*., 2006). However, in India, the diesel energy coefficient of 56.31 MJ/l was suggested by different researchers (Gopalan *et al*., 1978; Binning *et al*., 1983). The energy input of diesel fuel is calculated using the following formula:

$E_f = DEC \times AFC$ .... (2)

Where,

Ef = Fuel input energy, MJ/ha

DEC = Diesel energy coefficient, 56. 31 MJ/l

AFC = Amount of fuel consumed, l/ha

Machinery

The total lifetime energy cost of machinery is estimated by aggregating the combined costs of raw materials, fabrication, spare parts, and maintenance. The average energy demand value of a piece of equipment is equal to 109 MJ/kg (Pimentel, 1992). This value was obtained from steel production energy of 62.8 MJ/kg (Doering, 1980), fabrication and assembly energy of 8.4 MJ/kg, and repair and maintenance energy of 37.7 MJ/kg (Fluck, 1985). The energy for production and maintenance for machinery was taken 76 MJ/kg for tractor and combines and 111 MJ/kg for tillage implements (Arvidsson Johan, 2010). Key machinery considered in this paper were four-wheeled used for land preparation, sowing and transportation. The characteristics of these machines are given in **Table 2**. To calculate the energy input used in machinery production or repair, the following formula was used.

$Eim = (MTR \times M) / (L \times C_e)$.... (3)

Where:

E_{im} = Machinery input energy, MJ/ha

MTR = Energy used to manufacture, transport and repair (for tractor, 76 MJ/kg and farm machinery, 111 MJ/kg)

M = Mass of machinery, kg

L = Life of machinery, h

C_e = Effective Field Capacity of farm machinery, h/ha

Pesticides, insecticides and herbicides

The application of pesticides, insecticides and herbicides are mostly used in all crops areas because of the massive attack of insect, pest and various kinds of weeds. The manufacture of pesticide consumes approximately 101.2 MJ and 238 MJ/l of energy for insecticides and herbicides, respectively (Doering, 1980). Almost similar figures were suggested by (Pimentel, 1992; Anon, 2004; Hulsbergen *et al*., 2001). The amount of pesticide energy input (120 MJ/kg) is adopted as per reported by (Binning *et al*., 1983).

The energy input of pesticides is computed using the following formula:

$Ep = PEC \times APA$.............. (4)

Where:

Ep = Pesticide input energy, MJ/ha

PEC = Pesticide energy coefficient: 120 MJ/kg for insecticide or 238 MJ/kg for herbicide

APA = Amount of pesticide applied, kg/ha

Fertilizers

Energy requirements for the production and transport of commercial chemical fertilizers as estimated by (Samootsakorn, 1982) are 80 MJ/kg, 14 MJ/kg and 9 MJ/kg for N as anhydrous ammonia, P as normal super phosphate (P_2O_5) and K as muriate of potash (K_2O), respectively. Approximately the same amount of energy for N is also estimated by (Pimentel 1992; Chamsing *et al*., 2008; Tippayawong *et al*., 2003). In India, the fertilizer energy coefficient is used as 60.6 MJ/kg for N, 11.10 MJ/kg for P and 6.70 MJ/kg for K (**Table 1**). The energy input of fertilizer N, P and K was calculated using the formula:

$Efr = NEC \times ANA$.................... (5)

Where:

Efr = Fertilizer input energy, MJ/ha

NEC = Fertilizer energy coefficient, 60.6 MJ/kg for N 11.10 MJ/kg for P or 6.70 MJ/kg for K

ANA = Amount of nutrient ap-

Table 1 Energy conversion factors as adopted /advised

Particulars	Equivalent energy (MJ)
Human Power	
(a) Adults man, Man-hour	1.96
(b) Woman, Woman-hour	1.57
Tractor, hour	332.00
Diesel, liter	56.31
Farm machinery, kg	62.70
Chemical Fertilizers, kg	
Nitrogen (N)	60.60
Phosphorus (P)	11.10
Potash (K)	6.70
Plant protection, kg	
Superior chemical (Granular)	120.00
Inferior chemical	10.00
Liquid chemical, ml	0.102
Farm Yard Manure, kg (dry mass)	0.30
Crop Produce (grain), kg	
Rice	14.70
Wheat	15.70
Chickpea	15.06
Mustard	22.64

Source: Gopalan *et al.* (1978) & Binning *et al.* (1983)

plied, kg/ha

Yield energy output

The crop yield data considered in this paper are obtained from experiment conducted during 2003-2007. The farm production (i.e. grain yield) was also converted in terms of energy (MJ) output using three year average yield under different crops of selected sequences and units of energy as available (Gopalan *et al*., 1978). In the calculations, the energy equivalents used as in **Table 1** for different crops was adopted. The following formula is used to calculate the yield energy output:

EOut = *YEC* × *YH*....................(6)

Where:

EOut = yield energy output, MJ/ha

YEC = yield energy coefficient, 14.70, 15.70, 15.06 and 22.64 MJ/kg of rice, wheat chickpea and mustard yield

YH = yield per ha, kg/ha

Statistical Analysis

The net return and output energy data were subjected to analysis of variance as per the procedure given (Little and Hills, 1978), and treatment means were compared using critical difference (CD) defined as least significant difference beyond which all the treatment differences are statistically significant as CD = ($\sqrt{2}$ V E r^{1}) t 5 % where VE is the error variance, r the number of replications of the factor for which CD is calculated t 5 % the table value of t at 5 % level of significance at error degree of freedom.

Results and Discussion

Energy Utilization in Farm Machineries Operation

Energy used to manufacture, transport and repair of machinery (i.e. farm power & farm machinery) MTR is calculated and given **Table 2**. The energy use in fuel and machinery for tillage and sowing operation in various crops are shown in **Table 3**. The MTR energy was highest in direct seeding (T_1) treatment (1,232 MJ /ha) followed by manual transplanting (T_5) (1197 MJ/ha) and lowest was mechanical transplanting (620 MJ/ha) in unpuddled field (T_4) respectively. It was due to the greater mass and numbers of machineries used for the field operation and crop establishment. The manual transplanting (T_5) consumed highest operational energy (6,455 MJ/ha) and lowest 3,467 MJ/ha in drum seeding (T_2) in wet field condition. The mechanical transplanting in puddled field (T_3) consumed second largest energy followed by 3,972 and 3,656 MJ/ha in direct seeding (T_1) and mechanical transplanting in unpuddled field (T_4). The largest energy was invested in the field where puddled operation was performed due to higher diesel energy used (Chaudhary *et al*., 2004; Chaudhary *et al*., 2006c).

Table 2 Energy for different machineries used for each operation

Particulars	Farm Power	Farm Implement	Total Energy, MJ/ha
Energy for harrow, 14 discs	Tractor	Harrow	
Mass, kg	10,000	400	
Field capacity, h/ha	0.45	0.45	
Life, h	12,000	2,500	
MTR energy, E_{im}, MJ/ha	140.7	39.5	180.2
Energy for cultivator, 9 tines		Cultivator	
Mass, kg	10,000	220	
Field capacity, h/ha	0.4	0.4	
Life, h	12,000	2,000	
MTR energy, E_{im}, MJ/ha	158.3	30.5	188.9
Energy for peg type puddler		Puddler	
Mass, kg	10,000	90	
Field capacity, h/ha	0.4	0.4	
Life, h	12,000	2,500	
MTR energy, E_{im}, MJ/ha	158.3	10.0	168.3
Energy for multi crop seed drill		Seed drill	
Mass, kg	10,000	300	
Field capacity, h/ha	0.32	0.32	
Life, h	12,000	2,000	
MTR energy, E_{im}, MJ/ha	197.9	52.0	249.9
Energy for self propelled transplanter		Rice transplanter	
Mass, kg	0	320	
Field capacity, h/ha	0	0.74	
Life, h	0	3,000	
MTR energy, E_{im}, MJ/ha	0	16.0	16.0
Energy for drum seeder		Drum seeder	
Mass, kg	0	16	
Field capacity, h/ha	0	0.15	
Life, h	0	1,000	
MTR energy, E_{im}, MJ/ha	0	11.8	11.8
Energy for wooden planker			
Mass, kg	10,000	0	
Field capacity, h/ha	0.52	0	
Life, h	12,000	0	
MTR energy, Eim, MJ/ha	121.8	0	121.8

MTR energy - Energy in MJ/ha used to manufacture, transport and repair machinery (i.e. farm power & farm machinery)

The amount of diesel in tillage and puddling operation was highest in mechanical transplanting with puddled (T_3) field (91 l/ha) followed by manual transplanting in puddled (T_5) field (81 l/ha). However, the higher input energy used in manual transplanting was because of more contribution of labour energy (10 %) as compared to other treatments in total operational energy up to the crop establishment (**Table 3**). It was noticed that 356 man-h/ha labour used in manual transplanting (T_5), however, 125 man^{-h}/ha labour consumed in mechanical transplanting (T_3 & T_4). Result revealed that the direct seeding (T_1) saved about 34 percent and drum seeding (T_2) saved about 46 percent energy input as compared to manual transplanting (T_5) in machineries used up to crop establishment. Similar results were also reported by authors (Chaudhary *et al*., 2006d).

When compared the energy in between Rabi (winter season) crop, the chickpea and mustard consumed 2,083 MJ/ha. However, the wheat used only 627 MJ/ha up to crop establishment. It was due to the fact that the wheat crop sown in no-till conditions, whereas, other two crops like mustard and chickpea were sown in the field after one harrowing + one cultivator + one planking and the machine used was multi crop seed drill that consumed about 2,083 MJ/ha energy.

Source-Wise Energy Utilization Pattern

The item/source wise energy dynamics is presented in **Table 4**. The different sources are utilized for the crop production. It is revealed that the highest energy was consumed in fertilizer followed by diesel fuel for pumping irrigation water, operational energy in machineries, labours and seed in all cropping systems (Chaudhary *et al*., 2006a). Very less amount was consumed in chemical applied for insect, pest and herbicides. This pattern was also seen in other two cropping systems. It was noticed that input energy consumed 40, 27, 14 and 7.7 percent in fertilizer, diesel fuel for irrigation, machineries, and labour of total energy used, respectively, for crop production in rice-wheat system. The trends are in agreement with other workers (Chaudhary *et al*., 2009). However, the energy spent in seed and insecticides, pesticides & herbicides was found to be 5 and 2 percent respectively. The less share of total input energy of different inputs was observed in rice-chickpea and rice-mustard system, which was 38 & 48 percent as fertilizer, 25 & 23 percent as diesel in irrigation, 20 & 17 percent as machinery and 5 & 9 percent as labour respectively. This highest input energy in fertilizer was due to higher energy invested for manufacturing and transportation which resulted the more value of energy coefficient. The second rank of energy consumed in the form of diesel fuel in centrifugal pump for irrigation purposes (Chamsing *et al*., 2008; Chaudhary *et al*., 2006d) which was also due to greater energy coefficient of diesel fuel for manufacturing of petroleum materials. The machinery part also consumed good amount of input energy (i.e.10 %) because of MTR energy and diesel fuel energy. The total labour consumed was about 8 percent of total input energy in rice-wheat system.

When compared operation wise energy among treatments of rice-

Table 3 Energy consumed in farm machineries used for tillage and sowing operation during crop establishment in different crops

Items	Diesel		Human		Machinery (MTR), MJ/ha	Total Energy, MJ/ha
	Quantity, l/ha	Energy, MJ/ha	Quantity, man^{-h}/ha	Energy, MJ/ha		
Kharif crop (Rice)						
T_1: Direct seeding (2 harrow + 2 cultivator + 2 planking)-dry bed	47	2,647	48	94	1,232	3,972
T_2 : Drum seeding (2 harrow + 2 cultivator + 2 planking)-wet bed	41	2,309	84	165	994	3,467
T_3 : Mechanical transplanting (2 harrow + 1 planking +2 passes of puddler)- puddled	91	5,124	116	227	835	6,186
T_4 : Mechanical transplanting (2 harrow + 2 planking)- unpuddled	51	2,872	84	165	620	3,656
T_5 : Manual transplanting (2 harrow + 2 cultivator + 1 planking +2 passes of puddler)- puddled	81	4,561	356	698	1,197	6,455
Rabi crops						
Wheat (No-till)	24	338	20	39	250	627
Chickpea (1 harrow + 1 cultivator + 1 planking)	18	1,295	24	47	741	2,083
Mustard (1 harrow + 1 cultivator + 1 planking)	18	1,295	24	47	741	2,083

wheat system, the mechanical transplanting in unpuddled field (T_4) used lowest diesel energy for pumping of irrigation water (i.e. 10,699 MJ/ha) which is 15 percent less than manual transplanting (T_5). However, the direct seeded (T_1) required less diesel pumping energy about 9 percent in comparison to manual transplanting. This is because of the direct seeded rice (T_1) is sown in dry field by use of machinery, however, manual transplanted rice is done puddled field. Moreover, the puddling operation required significant water pumping energy in manual transplanting in puddled condition (Chaudhary *et al*., 2008).

Human labour energy input was obviously the highest in the manual transplanting (T_5) due to more number of labour required for transplanting, whereas, drum seeded (T_2) treatment also required same amount of human energy, it was because of higher labour invested in manual weeding purpose. Moreover, labours energy also consumed for operation of the drum seeder in wet field condition. However, the lowest human energy consumed in mechanical transplanting puddled field (T_3) which was 13 percent less in comparison to manual transplanting (T_5). Less labour energy consumed in mechanical transplanting was because of mechanization in transplanting of seedlings which attributed about 250 man-h/ha in manual transplanting (T_5) as compared mechanical 50 man^{-h}/ha in T_3 & T_4. Moreover, the less labour energy was spent in weeding operation as when puddling operation was performed in treatment. Seed energy input was apparently high for direct (T_1) and drum seeded, T_2 (2,452 MJ/ha), especially for manual transplanting, T_5 (1,938 MJ/ha), because more quantity of seeds was required for direct seeding by seed drill and drum seeder as compared to manual transplanting where seedlings are required to transplant of the rice crop. Moreover, for growing of seedlings requires less seed input (30 kg/ha) in T_5 as compared to 60 kg/ha in T_1 & T_2. Similar pattern are also sown in rice-chickpea and rice-mustard.

Operation-Wise Input Energy Utilization Pattern

The operation wise input energy dynamics is presented in **Table 5**. The energy consumed in land preparation was varied from 3,007 to 7,222 MJ/ha in rice-wheat, 4,519 to 8,835 MJ/ha in both the systems as rice-chickpea and rice-mustard. Energy input for land preparation on average all treatments contributed

Table 4 Energy dynamics (MJ/ha) of item wise of different cropping systems after various rice crop establishments

Treatments	Seed	Fertilizers	Pesticides/ Insecticide	Diesel (Pump)	Machinery			Labour	Total Energy
					Diesel	MTR	Total		
Rice-wheat									
T_1	2,452	18,364	881	11,487	3,998	1,482	3,363	3,363	4,2027
T_2	2,452	18,364	881	12,163	3,660	1,244	3,434	3,434	42,197
T_3	2,011	18,364	681	12,107	6,476	1,085	2,964	2,964	43,686
T_4	2,011	18,364	681	10,699	4,223	870	3,136	3,136	39,984
T_5	1,938	18,364	681	12,557	5,913	1,447	3,434	3,434	44,332
Mean	2,173	18,364	761	11,803	4,854	1,226	6,080	3,266	42,445
Rice-chickpea									
T_1	1,786	12,526	753	8,109	3,942	1,972	3,653	3,653	32,741
T_2	1,786	12,526	753	8,784	3,604	1,734	3,724	3,724	32,911
T_3	1,345	12,526	553	8,728	6,419	1,576	3,254	3,254	34,400
T_4	1,345	12,526	553	7,320	4,167	1,361	3,426	3,426	30,698
T_5	1,271	12,526	553	9,179	5,856	1,937	3,724	3,724	35,046
Mean	1,507	12,526	633	8,424	4,798	1,716	6,514	3,556	33,125
Rice-mustard									
T_1	1,063	18,364	553	8,784	3,942	1,972	3,559	3,559	38,238
T_2	1,063	18,364	553	9,460	3,604	1,734	3,630	3,630	38,408
T_3	622	18,364	353	9,404	6,419	1,576	3,160	3,160	39,897
T_4	622	18,364	353	7,996	4,167	1,361	3,332	3,332	36,195
T_5	549	18,364	353	9,854	5,856	1,937	3,630	3,630	40,543
Mean	784	18,364	433	9,100	4,798	1,716	6,514	3,462	38,656

T_1: Direct seeding (2 harrow + 2 cultivator + 2 planking)-dry bed;
T_2: Drum seeding (2 harrow + 2 cultivator + 2 planking)-wet bed;
T_3: Mechanical transplanting (2 harrow + 2 cultivator + 2 planking +2 passes of puddler)- puddle;
T_4: Mechanical transplanting (2 harrow + 2 cultivator + 2 planking)- unpuddled;
T_5: Manual transplanting (2 harrow + 2 cultivator + 2 planking +2 passes of puddler)- puddled

11, 19 and 16 percent of total energy inputs for rice-wheat, rice-chickpea and rice-mustard, respectively. However, the puddled field in manual transplanting (T_5) consumed highest input energy for land preparation i.e. 7,322 MJ/ha. The similar pattern is shown in other two systems. In rice-wheat system, lowest energy consumed for land preparation in T_4 treatment than T_5 (i.e. 59 %), however, direct and drum seeding (T_1 & T_2) required about 53 percent less energy than manual transplanting in puddled field (T_4). It was due to no tillage operation was performed in flooded water (i.e. puddling) for rice crop establishment in treatment T_1 & T_2. The higher energy was spent due to puddling operation in T_3 (6,945 MJ/ha) and T_5 (7,322 MJ/ha) other than tillage operation in dry field (Chaudhary *et al*., 2004; Chaudhary *et al*., 2006c). Seed and sowing input consumed about 9 and 6 percent of total input energy in rice-wheat and both rice-chickpea, rice-mustard, respectively. In weeding and intercultural operation spent about 3 percent of total input energy in all systems, whereas, it was noticed from **Table 5** that the puddled field condition consumed very less energy (941 MJ/ha) as compared to unpuddled condition as direct/ drum seeded (T_1 and T_2 i.e. 1411 MJ/ha) in rice-wheat systems.

The highest energy is invested in the fertilizer application in all cropping systems, which varied from 12,526 to 18,364 MJ/ha i.e. 43 percent of total input energy (Chaudhary *et al*., 2009; Chaudhary *et al*., 2006b; Gopalan *et al*., 1978). The second rank in consuming the input energy has got to provide the irrigation to the crops, which is about 26 percent of total energy use for crop production (Chaudhary *et al*., 2008; Chamsing *et al*., 2008). In comparison among the treatment, it revealed that direct (T_1) and drum seeded (T_2) (i.e. 11,942 MJ/ha) consumed higher irrigation energy (i.e about 12 %) as compared to transplanted rice treatment (i.e. 10,528 MJ/ha). This is because of less water requirement in whole crop production in manual transplanting (T_5) after the seedling transplanted in field. The direct (T_1) and drum seeded (T_2) rice required 2 to 3 irrigations more where it was seeded in field one month before that of transplanted rice crop. Meanwhile, the same day the, sprouted rice seed were placed in the field for seedling growth for transplanted rice. The harvesting and threshing spent about 6 and 2 percent in plant protection of crop of total input energy.

Energy Dynamics in Systems

The system wise energy dynamics are presented in **Table 6**. The comparison of different cropping systems, the rice-chickpea consumed less input energy (i.e. 30,698 to 35,046 MJ/ha) followed by rice-mustard (varied from 36,195 to 40,543 MJ/ha) and rice-wheat

Table 5 Operation wise energy dynamics (MJ/ha) different cropping systems after various rice crop establishments

Treatments	Land Preparation	Seed & sowing	Intercultural / weeding	Fertilizer	Plant protection	Irrigation	Harvesting & Threshing	Total Input Energy, MJ/ha
Rice-wheat								
T_1	3,385	3,667	1,411	18,364	881	11,942	2,378	42,027
T_2	3,385	3,837	1,411	18,364	881	11,942	2,378	42,197
T_3	6,945	3,851	941	18,364	681	10,528	2,378	43,686
T_4	3,007	3,851	1,176	18,364	681	10,528	2,378	39,984
T_5	7,322	4,119	941	18,364	681	10,528	2,378	44,332
Mean	4,807 (11.4)*	3,865 (9)	1,176 (2.8)	18,364 (43.3)	761 (2)	11094 (26.3)	2,378 (5.6)	42,445 (100)
Rice-chickpea								
T_1	4,897	2,944	1,254	12,526	753	8,485	1,882	32,741
T_2	4,897	3,114	1,254	12,526	753	8,485	1,882	32,911
T_3	8,457	3,128	784	12,526	553	7,071	1,882	34,400
T_4	4,519	3,128	1,019	12,526	553	7,071	1,882	30,698
T_5	8,835	3,396	784	12,526	553	7,071	1,882	35,046
Mean	6321 (19)	3142 (9.4)	1019 (3.1)	12526 (37.8)	633 (1.9)	7637 (23.03)	1882 (5.7)	33159 (100)
Rice-mustard								
T_1	4,897	2,222	1,254	18,364	553	9,223	1,725	38,238
T_2	4,897	2,392	1,254	18,364	553	9,223	1,725	38,408
T_3	8,457	2,406	784	18,364	353	7,809	1,725	39,897
T_4	4,519	2,406	1,019	18,364	353	7,809	1,725	36,195
T_5	8,835	2,674	784	18,364	353	7,809	1,725	40,543
Mean	6,321 (16)	2,420 (6.3)	1,019 (3)	18,364 (47.5)	433 (1.1)	9,936 (25.7)	1,725 (4.5)	38,656 (100)

*Parenthesis values are given in percent of total input (varied from 39,984 to 44,332 MJ/ha). The reduction in input energy was about 22 and 14 percent in rice-chickpea system as compared to rice-wheat and rice-mustard system. System wise energy analysis indicated that the highest input energy was (44,332 MJ/ha) consumed in manually transplanted (puddled) followed by (43,686 MJ/ha) in mechanically transplanted (puddled) and lowest was 39,984, 41,2027 and 42,197 MJ/ha in mechanically transplanted (unpuddled) and drum seeded, respectively in rice-wheat system. The input energy of treatment manually transplanted (T_5) was found higher due to higher use of inputs as in tillage and sowing operation as compared to direct and drum seeded (T_1 and T_2) in which the tillage operation was minimum (Chaudhary *et al.*, 2006d).

Energy Production (Output) Pattern

In rice-wheat system, the output and net return energy are found to be non-significant among the treatments. However, the output energy was highest in drum seeded, T_2 (212,798 MJ/ha) closely followed by direct seeded, T_1 (211,350 MJ/ha) and lowest was 193,916 MJ/ha in manually transplanted in puddled (T_5) which is statistically at par. The net return energy of the system was found to be high in drum seeded, T_2 (170,595 MJ/ha) followed by direct seeded, T_1 (169,271 MJ/ha) and lowest was 149,390 MJ/ha in manually transplanted in puddled (T_5) which were significant at par. In rice-chickpea, the output energy in the direct and drum seeded (T_1 & T_2) were significantly higher compared to other treatments (T_3, T_4 & T_5) which were statistically at par. The study revealed about 11 and 9.5 percent higher output energy was used in direct (T_1) and drum seeded (T_2) in comparison to manual transplanting (T_5), whereas, the net return energy were 15 and 14 percent higher. The similar pattern of energy was also found in net return energy in rice - chickpea systems.

The direct and drum seeded (T_1 & T_2) required about 5 percent less input energy and gave 8 to 9 percent higher output energy as compared to manually transplanted in puddled field (T_5). Whereas, in case of mechanically transplanted T_4 (unpuddled), it required 10 percent less input energy and provided 6 percent higher output energy. However, in puddled condition mechanically transplanted T_3 required 1.5 percent less input energy and gave 3 percent higher output energy as compared to manually transplanted (puddled) T_5. Similar pattern of energy dynamics were also found in rice-chickpea and rice-mustard systems. The input energy in manually transplanted (T_5) treatment was found higher due to higher use of inputs as in tillage operations, sowing operation as compared to direct seeded (T_1) and drum seeded (T_2) in which the tillage operation was minimum so that energy consumed in diesel was very less (Chaudhary *et al.*, 2006c; Chaudhary *et al.*, 2006d). The fertilizer consumed highest input energy and it was due to use of chemical fertilizer. The irrigation has second rank in consuming the input energy it was because of higher use of fossil energy (i.e. diesel). The output energy and net return energy was found higher in drum seeded and direct seeded due to its higher grain yield resulted by good crop establishment in minimum tillage and unpuddled field (Chaudhary *et al.*, 2009). The output and input ratio was found to be high in T_4 (5.2) and followed by T_1 and T_2 (5.0) and lowest was in T_5 (4.6).

Table 6 Input, output and output energy pattern (MJ/ha) of different cropping systems as influenced by rice planting methods (4 year pooled data)

Treatments	Input, energy, MJ/ha	Output, energy, MJ/ha	Net return, energy, MJ/ha	Output-input ratio
Rice-wheat				
T_1	42,027	211,361	169,271	5.0
T_2	42,197	212,711	170,595	5.0
T_3	43,686	199,463	155,980	4.6
T_4	39,984	206,613	166,333	5.2
T_5	44,332	193,483	149,390	4.4
SEm ±	-	6,119	6,119	0.15
CD at 5 %	-	NS	NS	NS
Rice-chickpea				
T_1	38,238	166,410	128,885	4.4
T_2	38,408	166,927	129,377	4.3
T_3	39,897	152,197	113,279	3.8
T_4	36,195	152,055	116,339	4.2
T_5	40,543	149,253	109,725	3.7
SEm ±	-	2,262	2,262	0.065
CD at 5 %	-	7,492	7,491	0.22
Rice-mustard				
T_1	32,741	153,078	121,050	4.7
T_2	32,911	155,559	123,505	4.7
T_3	34,400	141,541	108,120	4.1
T_4	30,698	139,939	109,720	4.6
T_5	35,046	138,392	104,361	3.9
SEm ±	-	1,831	1,931	0.06
CD at 5 %	-	6,064	6,065	0.19

Conclusions

The results revealed that the rice-wheat consumed highest input energy but it also produced highest output energy which leads to highest net return energy as compared to rice-chickpea and rice-mustard system. The highest input energy could be consumed in fertilizer followed by diesel fuel for pumping irrigation water, operational energy in machineries, labours and seed under all cropping systems. Very less energy was consumed in respect of chemical applied for insect, pest and weed control purposes. The direct and drum seeded saved about 34 and 46 percent, respectively, in input energy as compared to manual transplanting for machineries. Further, drum and direct seeded treatments produce highest net return in case of rice-wheat about 15 and 14 percent as compared to manual transplanting. Thus, it was concluded that the direct and drum seeded treatment is advisable for saving energy under rice based cropping systems in tropical India.

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An Autogroover Machine for Making Helical Grooves on Rollers Used in Roller Ginning Machines

by

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Abstract

Roller gins are the most popular ginning machines used in India. During continuous operation of the double roller gin, due to friction between the roller and knife, the rollers become smooth. The grooving of the rollers after every 16 to 20 working hours is necessary to increase the rough surface for the lint to adhere to the roller at a faster rate. Since grooving is done manually with hacksaw, the grooves are not uniform, time consuming, laborious and many a times the grooving is not done at the right time. This not only affects the lint quality and productivity of ginning machine but also damages the roller affecting its durability. To overcome these problems an auto-grooving machine has been developed to make helical grooves on the roller. It consists of main frame, head stock, tail stock and a cutter assembly mounted on a movable trolley. The rotary motion of the roller, forward motion of the trolley and the rotary motion of the saw blade cutter was synchronized with suitable drive mechanism. The machine was successfully tested and its performance was found to be satisfactory. The machine can groove the roller in ten minutes with 18 grooves on it. The equally spaced grooves of uniform depth and breadth of 2 mm were cut with precision and accuracy. The regrooving on the same impression after reduced roller diameter was also successfully carried out. The autogroover machine can effectively replace the existing manual method of grooving.

Introduction

Roller gins are the most popular ginning machines used in India. Ginning machines are devices which separates mechanically the fibres and seed of the seed cotton. Normally single roller (SR) gins, double roller (DR) gins, and rotary knife gins are used for ginning. The roller gins work on the principle of Ma-carthy's gin. There should not be any damage to the properties of the ginned lint and quality of seed obtained while processing in gins. Besides, maintaining the seed quality and ginning percentage, preservation of fibre properties viz. 2.5 % span length, length uniformity ratio, micronaire value, tenacity are equally important for cotton.

Ginneries are presently using different materials for rollers viz., chrome composite leather, newspapers, walrus leather, rubber-canvas composite material, cotton woven fabrics, etc. Among these materials the chrome composite leather is the most widely used roller material. The roller of a given length is made of chrome composite leather washers, which are compressed at a pressure of about (1.373 MPa) on a steel shaft. The shape of steel shaft inside the discs can be square, rectangular, pentagonal, etc. The washers are made of partly finished chrome tanned leather sheet, each 0.75 to 1.25 mm in thickness, which are glued together. Each washer consists of 10 to 20 numbers of leather flaps. The sheet is finally cut with the help of a die to circular shapes to make the washers. Individual washers are perfectly stitched with single cotton thread. Each washer is about 13 to 19 mm in thickness. The ginning roller is made by inserting required number of washers over a steel shaft. By applying optimum pressure on the inserted washers, the washers are compressed together, which forms a ginning roller. This roller is finished on a lathe machine and grooved.

The surface of the chrome composite leather roller gets polished very fast while running. During the continuous operation of the DR gin, due to friction between the roller and knife, the rollers become smooth and the surface of leather roller needs to be roughened by cutting grooves to get optimum ginning output. Due to this the ginning out put of the machine drops continuously with running time. To overcome this, the chrome leather roller is required to be removed from the machine and then the surface is roughened by cutting grooves. The surface of the roller is given a smooth finish and helical grooves of 2 mm width and depth are to be cut on it such that the spacing between the consecutive grooves is uniform throughout the length of the roller. The purpose of the groove is two-fold namely, 1) to prevent abortive seeds and motes from sticking under the knife; and 2) to provide place for the fibres to enter readily under the knife, assuring a constant flow of fibres over the roller, there by increasing the production. The helix makes a half to three-fourth revolution about the length of the roller. Rollers should be grooved every day before the start of the ginning or once in every 16-20 working hours. The grooving of the rollers is necessary to increase the rough surface for the lint to adhere to the roller at a faster rate. The grooves should not be appreciably wide or distinctly V-shaped.

Table 1 Specifications of the autogroover machine

Particulars	Values
Cutter blade diameter, mm	100
Cutter blade thickness, mm	1.5
Cutter blade speed, rpm	1,400
Power required to drive cutter blade, HP	1
Power required to drive the roller and trolley, HP	1
Trolley size, mm × mm	600 × 350
Number of groves	18
Overall size of the machine, mm × mm × mm	2000 × 600 × 660

This process is very labour intensive and in India is done preferably manually by using saws. For carrying out grooving the roller is mounted on a stand. Two men pull a saw in a reciprocating manner by standing on either side of the roller. The roller has to be rotated by hand while cutting to form a helical groove. Since uniform rotation of the roller with hand while cutting is not ensured the successive grooves cut on the roller are never parallel to each other and sometimes may overlap. Since it is a manual operation, the uniformity in depth and width of groove cannot be achieved.

Some ginneries use marble cutting tool and grooving is done by rotating the roller with one hand while moving the motor along with the tool on the other hand on the surface of the roller in a helical direction. This operation is very dangerous as the motor has to be held in hand with the cutting tool rotating at very high rpm and may cause serious injury to the operator. The risk of getting electric shock also is very high which makes the grooving a very risky job. In this operation also the grooves made are never parallel to each other and the depth of grooving also varying which causes damage to the fibre during ginning.

Some ginneries also use conventional grooving machines in which the roller has to be rotated by hand as well as the trolley carrying the cutting tool has to be moved in the forward direction by hand. Due to these manual operations the operator does not have any control on the forward speed and the angle of rotation of the roller which results in grooves with non uniform spacing. Also the non uniform grooving has an adverse effect on the fibre and seed quality and on the production capacity of the machine.

To overcome these difficulties noticed in conventional methods of grooving an auto-grooving machine has been developed to make helical grooves ensuring precise depth control and with uniform spacing between two grooves.

Materials and Methods

An autogroover machine has been designed. The 2D and 3D drawings of the designed machine were prepared. A prototype of an autogroover machine has been developed and fabricated at the Ginning Training Centre of Central Institute for Research on Cotton Technology (CIRCOT), Nagpur. The testing of the machine was carried out. The performance of the autogroover machine in terms of the capacity and energy consumption was assessed.

Results and Discussion

Design and Fabrication

The autogroover consist of a main frame, a head stock, a tail stock and a cutter assembly mounted on a movable trolley developed for making helical grooves on leather rollers. The rotary motion of the roller, forward motion of the trolley carrying the cutter assembly and rotary motion of the cutter blade were synchronized with appropriate mechanisms to cut precise groove on the roller. The machine was provided with an indexing mechanism for making consecutive helical grooves parallel to each other at a specified distance on the roller. Adjustments viz., change of angle of helical grove, number of grooves, distance between successive grooves, depth and width of grooves, speed of roller, speed of cutting blade and trolley could be made easily for carrying out smooth grooving of the roller.

Base Frame

The base frame of the roller grooving machine was kept as 2.4 m length, 0.6 m width and 0.66 m height with channel section frame of 100 × 50 mm. The frame was supported at the four corners by four legs made of the same section with the total height of the frame at 0.66 m. The head stock and tail stock were mounted on either end of the frame to hold the roller firmly in a horizontal direction parallel to the length of the frame. Two rails were provided on the top of the frame to move a cutting blade assembly consisting of a cutting tool with driving motor from one end to the other. Accurate machining was done to obtain the geometric centre of chuck fixed on the headstock and revolving centre of the tailstock concentric in one line. The rails for guiding the movement of the trolley were made with 50 mm square bar fixed on the top of the main frame on either sides.

Head Stock

The head stock consisted of a cast iron box having size, 270 mm length, 300 mm width and 350 mm height. The opposite faces were bored and fitted with a spindle having 50 mm diameter and 500 mm length. On the inner side of the spindle a 150 mm true chuck was fitted to hold the roller. On the outer side of the spindle a bevel gear was mounted on bush bearing which could be rotated independent of the chuck. The spindle and the bevel gear are locked together by an indexing mechanism. This consists of an arm fixed on the spindle perpendicular to it and having a spring loaded nail which locks it to a hole made on the bevel gear. At the same radius a total of eighteen holes are made at 200 angles apart. The bevel gear was attached to a pinion gear which is mounted on a shaft fitted vertically on the base frame. On the bottom side of this shaft a sprocket was mounted. At the tail end another similar sprocket was mounted on a shaft attached vertically to the base frame. A continuous chain was mounted on these two sprockets and tightened by adjusting the tail end shaft position.

Tail Stock

A screw type tail stock was made with 50 mm screw shaft and 4 TP threading attached to a square nut connected to the top sliding block. Both the forward and backward movements were obtained by rotat-

Fig. 1 Schematic diagram of autogroover machine (Front elevation)

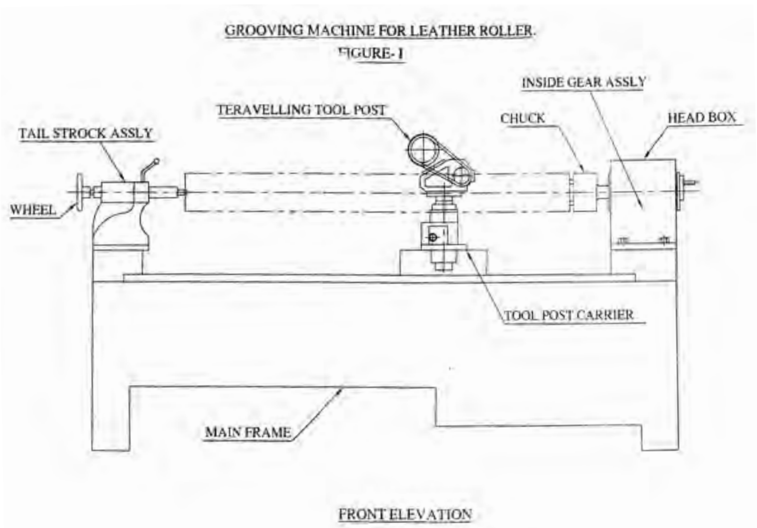
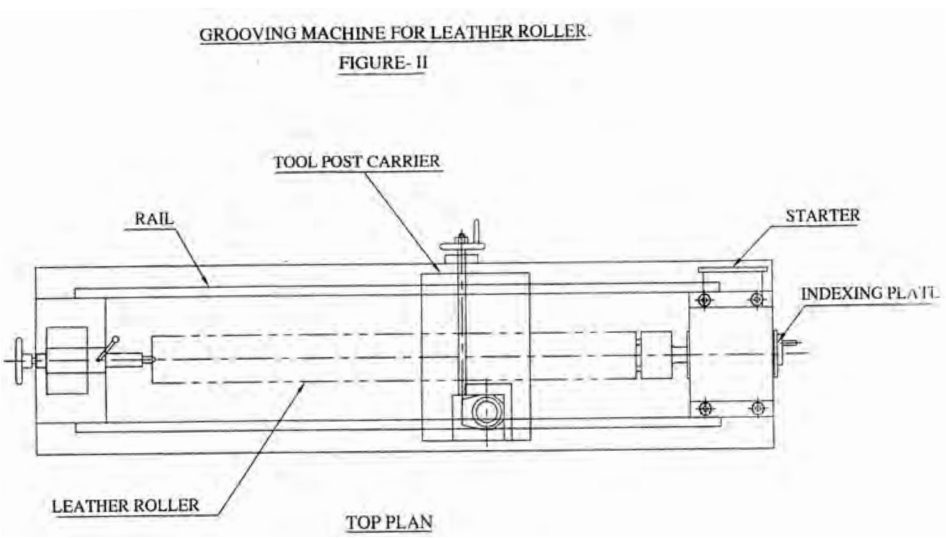


Fig. 2 Schematic diagram of autogroover machine (Top view)



ing a handle attached to the screw. The roller was secured between the chuck and the tail stock horizontally for grooving by moving the tail stock towards the chuck through rotation of a handle provided on the screw attached to the tailstock. The roller could be gripped by tightening the chuck on the head stock.

Cutter Assembly

A 600 mm × 350 mm horizontal trolley was fabricated with 45 × 45 × 5 mm L section material and mounted on 4 pulleys to slide on the rails provided on the main frame. A rotary saw blade and motor assembly was mounted on a sliding spindle on to the trolley. This assembly could be lifted or lowered to adjust the depth of groove by rotating a wheel attached to a gear box on which a spindle is mounted. The rotary saw cutter was fixed at an angle of 17o to the direction of forward movement of the trolley. The cutter blade was positioned exactly above the centre line of the roller. This trolley was locked to the chain provided on the bottom of the main frame.

Working of the Machine

The roller was mounted horizontally between the chuck and the revolving centre. The cutting circular saw was adjusted to just touch the roller by bringing the tool post carrier nearer to the chuck. Then the cutter saw was rotated by starting the motor and was slowly brought down by rotating the handle attached to the spindle of the gear box mounted on tool post carrier. By this way the depth of cut was suitably adjusted to 2 mm. Then the trolley was moved forward by starting the motor for the drive assembly. As the trolley with cutter saw moved forward, the roller rotated in clockwise direction as it was attached to the same shaft through a pinion and a bevel gear mechanism. This way the synchronization between the forward movement of the trolley and clockwise rotation of the roller was ensured in such a way that when the saw cutter moved from the head stock end to the tail stock end, the roller makes a rotation of 2,700. A helical groove was made on the surface of the roller when the trolley was moved forward. The indexing for making further grooves was done manually by adjusting the pin on the head stock spindle to lock with the successive holes on the bevel gear which is made to align the roller delinking from the trolley movement. A total of eighteen grooves were

Fig. 3 Schematic diagram of synchronization of tool post carrier with roller

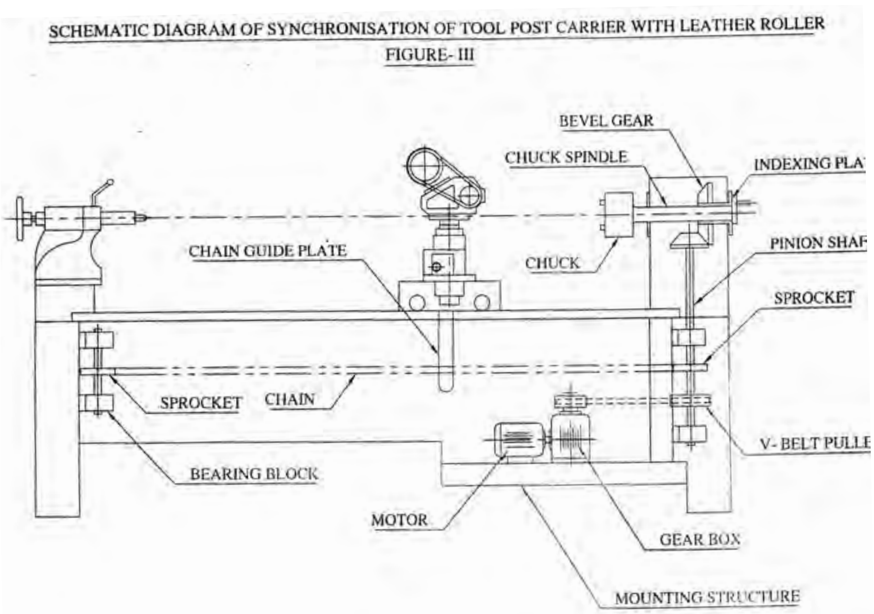


Fig. 4 Pictorial view of autogroover machine

Fig. 5 Pictorial view of manual grooving of leather roller

thus made on the roller.

Performance Evaluation

The developed machine was successfully tested at the Ginning Training Centre of Central Institute for Research on Cotton Technology (CIRCOT), Nagpur. The chrome composite leather rollers used in cotton ginneries were used for the trials. A roller was mounted on the autogroover machine and grooving was carried out. The necessary adjustments of indexing mechanism and the cutter assembly were carried out before starting the machine. The performance of the machine was found to be satisfactory. Precise and accurate helical grooves could be made on the roller with the help the machine. Equally spaced grooves of uniform depth and breadth of 2 mm were cut with precision and accuracy. Successive grooves could also be at the designed spacing between two grooves. A uniform spacing between the two successive grooves throughout the length of the roller was noticed. The re-grooving on the same impression after reduced roller diameter could also be carried out.

The actual time required for cutting a grove was found to be 30 seconds including the time required for forward and return movement of the trolley. The total time required for grooving the complete roller with 18 grooves was found to be 10 minutes. Six rollers were grooved with the machine in an hour.

The grooving on a similar roller was carried out with conventional manual method by a saw pulled by two men. Manually it takes an hour to groove the complete roller with 18 grooves. The depth, width and spacing of the grooves were not uniform throughout the length of the roller. Non uniform spacing and improper depth and width of the groves adversely affect the fibre quality and the ginning output. The autogroover machine can therefore successfully replace the existing manual method of grooving and thus avoid the drudgery involved in this operation.

Conclusions

An autogroover machine was designed and developed to make helical grooves on the roller of a roller ginning machine. The rotary motion of the roller, forward motion of the trolley and the rotary motion of the saw blade cutter were synchronized with suitable drive mechanisms. The machine was successfully tested, and its performance was found to be satisfactory. The machine was found to groove the roller in ten minutes with 18 grooves on it. Equally spaced grooves of uniform depth and breadth of 2 mm were cut with precision and accuracy. Regrooving on the same impression after reduced roller diameter was also successfully carried out. The autogroover machine can effectively replace the existing manual method of grooving and thereby avoid the drudgery involved in this operation.

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Potential of Variable Rate Application Technology in India

by

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Abstract

Farmers apply various agricultural inputs like seeds, fertilizers, weedicides, pesticides and water, based on recommendations emanating from research and field trials under specific agro-climatic conditions, which have been extrapolated to a regional level. Since soil types, soil nutrient status, weeds density, pests infestations and soil water vary not only between regions and between farms but also from plot to plot and within a field or plot, hence, there is a need to take into account such variability while going to cultivate a particular crop. The goal is to obtain more efficient use of applied inputs to improve economics to reduce any excess application that might cause environmental pollution. Agricultural technologies using the global positioning system (GPS) and geographic information systems (GIS) have started to change how farmers are managing crops. By utilizing these tools with an objective to manage existing field variability, variable-rate technology (VRT) has been evolved. VRT combines a variable-rate (VR) control system with application equipment to apply inputs at a precise time and/or location to achieve site-specific application rates of inputs. VR mounted on equipment, permits input application rates to be varied across fields in an attempt to site-specifically manage field variability. This type of strategy can reduce input usage and environmental impacts along with increasing efficiency and providing economic viability. A VRT essentially comprises of a locator (DGPS receiver), control computer and actuator (VRA software and controller) in an integrated manner to make VRT to work. Three different approaches exist to implement VRT viz: map-based, sensor-based and manual. The intra and inter field variability can be characterized by a number of factors like climatic conditions (hail, drought, rain, etc.), soils (texture, depth, nitrogen levels), cropping practices (no-till farming) and preventance of weeds and diseases. These factors can be assessed by two types of indicators (permanent indicators and point indicators). The permanent indicators are mainly soil indicators which provide the information about the main environmental constants. The point indicators helps to track a crop's status in terms of occurrence of water stress, nutrient stress, disease infestation, weed infestation, crop lodging etc . This information may derive from weather stations and other sensors (soil electrical resistivity, detection with the naked eye, satellite imagery etc.). Soil resistivity measurements combined with soil analysis make it possible to precisely map agro-pedological conditions. By catering to this variability, one can improve the productivity or reduce the cost of production and diminish the chance of environmental degradation caused by excess use of inputs

Introduction

The agricultural production has become stagnant in the post-green revolution period and horizontal expansion of cultivable lands became limited due to burgeoning population and industrialization. The food security for ever-increasing human population along with environmental protection and conservation of natural resources have emerged as the prime concerns for the sustainability of Indian and global agriculture. Unfortunately, the unprecedented increase in human population during past half century, from 3 billion during 1960 to currently 6 billion, is further expected to grow to 8.5 billion by 2025 (Paroda, 2009). Given a number of drivers and uncertainties that impinge on food production, the fact that close to 1 billion people are undernourished, there has to be concern as to whether we can feed 9 billion people in the future. The sheer numbers of people wanting to be fed by 2050 mean that the challenge for the agricultural community will be immense and this needs to be recognized by governments across the world in terms of their preparedness to invest in agriculture and natural resource management at hitherto unforeseen levels.

India is a vast agrarian country with total land area of 329 million ha and arable land area of 166 million ha. The population of India is growing at the rate of 1.7 % per year. The required food grain production by the year 2025 is 300 million ton that will necessitate further intensification of cropping system (Anonymous, 1996). The horizontal expansion of cultivable lands is going to be limited day by day due to increasing population and industrialization. Thus, the only option left is to increase the vertical yield, which is possible only by adopting the intensive cropping system. Food production in India has increased spectacularly from 69 million tones in 1965 to 242 million tones at present (Anonymous Economic Survey 2009) due to adoption of intensive cropping system and other improved crop production technologies. Now there are reports of increasing problems of environmental degradation in agricultural fields, especially in intensively cultivated regions such as the Indo-Gengetic plains (IGP). There is a great concern now about decline in soil fertility, decline in water table, rising salinity, resistance to many pesticide increase pesticide residues in environment (soil water and air) and degradation of irrigation water quality (Anonymous, 2006). Today, over-exploitation of ground water is a serious problem in many regions of India. The water table in the north western part of India, for example, is receding at an annual rate from 0.2 to 0.5 m. Soil salinity and water loggings are the other problems that have already spread to several parts of the India like IGP. In some part of India like Punjab, the mean fertilizer use in rice and wheat has become much higher than the recommended dose such uses can sometimes result in increased NO3 concentration in groundwater. There is a potential to save water between 2.56 to 7.3 % of in the fields with distinctive soil texture zones of Regions of Tekirdağ, Turkey and Karditsa (Thesally), Greece by applying FAO water application model (Turker *et al*., 2011). World agriculture contributes about 4 % of total global carbon dioxide emissions, the most important greenhouse gas. Other green house gases contribute to atmosphere due to intensive agriculture practice are methane and nitrous oxide (Anonymous, 2006).

Variability: The Basis of VRT Application

The conventional agronomic practices follow a standard management option for a large area irrespective of the variability occurring within and among the fields. Depleting natural resources, inefficient input utilization, over manipulation of soil and the high cost of fertilizers necessitate judicious use of every unit of resources. The time has come when it is of paramount significance to re-engineer the programmes with multidisciplinary approach for natural resource management. Care need to be taken to increase the input (fertilizer, weedicide, pesticide, irrigation water) use efficiency by the crops. For maximum efficiency of applied inputs, it is essential to deliver them in right quantity and at a rate to the plant so as to maximize uptake, avoiding inadequate and excess application. The uniform rate technology (URT) followed in conventional agriculture aggravate the problem of low productivity and environmental degradation. The conventional agriculture practices follow a standard management option for a large area, irrespective of the variability occurring within and among the field. Farmers have been applying various agricultural inputs like seed fertilizers, weedicides, pesticides and water, based on recommendations emanating from research and field trials and under specific agro-climatic conditions, which have been extrapolated to a regional level. Since soil types, nutrient status, weeds density, pests infestation and soil water vary not only between regions and between farms but also from plot to plot within a field, so there is a need to take into account such variability for an intended crop. There has been a growing public awareness about the adverse environmental impacts of increasing chemicalisation of agriculture in developing countries and the consequent loss of its sustainability. This has come from increasing air and water pollution caused by non-judious use of chemicals (fertilizers, weedicides, pesticides, etc.). In response to this, a new paradigm of sustainable or conservation agriculture is fast emerging which does not favour the blind pursuit of the goal of maximizing agricultural production at the cost of environmental degradation. Given this emerging scenario, a major challenge confronting agricultural scientists, economists and environmentalists is how to reconcile the (conflicting) goals of efficiency, defined in terms of maximization of net present value of agricultural production in the long run by using VRT for sustainable agriculture. The former is necessary for meeting the growing requirement of food and other agricultural produce of the rapidly increasing world population, particularly in developing countries and the latter for ecological and food security. The goal is to obtain the efficient use of applied inputs to reduce any excess application that might cause environmental pollution and to improve crop production economics. The input use efficiency can be improved by minimizing losses of water, nutrient and avoiding excess use of fossil fuel by following conservation tillage practice and optimal allocation of these inputs. Synchronizing with the demand of the crops and cropping systems, instead of piecemeal approach of improving single input use efficiency, there is need to find out synergistic combination among different inputs and integrated use of different inputs in a holistic manner to improve the overall input use efficiency. Variable rate technologies (VRT) needs to be developed for maximizing the use efficiency of different inputs under integrated input management for different crops and cropping systems under different agro-climatic regions and soil types through multi-disciplinary approach. The VRT is the application of technologies and principles to manage spatial and temporal vari-

Table 1 Various intra and inter-field variability factors

Factors	Parameters
Climatic Conditions	Hail Strom, Drought, Rain etc.
Soils	Soils Texture, Soil Structure, Soil Depth, Soil Nitrogen Levels etc.
Cropping Practices	No-Till Farming, Resource Conservation

Table 2 Various Techniques for Assessing Variability

Type	Purpose	Reported Technology
Surveys	Surveys are purposeful inventories of specific quantities and have been particularly useful in natural resource management. A first glace, the soil survey should be an important assets to the principles of VRT agriculture. However, existing soil surveys have proved of limited value in explaining spatial variability observed within fields. The value of the soil survey to VRT agriculture could be improved by intensifying map scales to fine scale resolutions needed in detailed environmental modeling applications or site-specific management (Moore *et al.*, 1993).	New data sources (e.g. digial orthophotos, airborne and satellite imagery and yield maps) and analysis techniques (e.g. and yield maps) analysis techniques (e.g. terrain analysis) make it possible to map soils at needed resolution (Bell *et al.*, 1995).
Interpolation of Point Samples	Spatial variability can be assessed by undertaking a sampling process. In this technique a number of points on some specific aspect are sampled and then interpolated to produce a spatial estimation (usually a map) of the whole area using a range of statistical procedures. Sampling technique depends on the nature of the entity of interest (i.e. some soil attribute, pest management,	Statistical techniques have been developed to estimate the temporal variability (Mc Bratey *et al.*, 1997; Stein *et al.*, 1997). Soil sampling for soil survey to find out a particular type of soil, it composition and some other soil attribute (Webster and Oliver, 1990). For pest management, interest may be in obtaining insect pest density maps either within a field or within a region and overtime (Fleischer *et al.*, 1997).
High Resolution Sensing	It is not physically or economically possible to accurately map certain soil properties, crop condition, or pest status without the use of high resolution sensing. Yield maps do not indicate the causes of the yield magnitude or its variability. In order to facilitate the farmers to adjust their management practices to specific conditions within a field at appropriate times during the growing season, the causes of variability needs to be quantified if any.	High resolution remote sensing of the growing crop will reveal stresses that impact the crop during the growing season (Scheper *et al.*, 1996).
Modeling	It is an important tool in precision agriculture to stimulate spatial and temporal variation in Soil Properties, Pests Management, Crop Yield and Performance of Cropping Systems.	Models have been developed and calibrated for specific purposes { Soil Properties (Verhagen and Bouma, 1997), Pests (Kropff *et al.*, 1997), Crop Yield (Barneett *et al.*, 1997) and Environmental Performance of Cropping Systems (Verhagen *et al.*, 1995)}, but have not been used extensively in spatial prediction.

Table 3 Various Components of Variable Rate Technology

Component	Description	Purpose
Remote Sensing	Remote sensing is the acquisition of information about an object or phenomenon, without making physical contact with the object. In modern usage, the term generally refers to the use of aerial sensor technologies to detect and classify objects on Earth. Remote sensing techniques play an important role in variable rate technology by providing continuous acquired data of agricultural crops.	Remote sensors image vegetation, which is growing on different soil types with different water availability, substrate, impact of cultivation and relief. These differences influence the state of the plants and cause heterogeneous regions within single fields. Hence, the heterogeneous vegetation acts as an interface between soil and remote sensing information, because vegetation parameters describing the state of the plants can be deduced from remote sensing imagery. The analysis of the variability occurring within the field was carried out by measuring soil and plant parameters through conventional methods as well as through spectral techniques using ground truth spectro-radiometer (350-1800 mm) and satellite data. The quality of remote sensing data consists of its spatial, spectral, radiometric and temporal resolutions.
Geographic Information Systems	A geographic information system is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. GIS is an organized collection of computer hardware, software, geographic data and personal designed to efficiently capture, store, update, manipulate, analyze and display all forms of geographically referenced information (Anonymous, 1997). No of such systems (like SAGA GIS, Quantum GIS, Whitebox GAT, Kalypso, MapWindow GIS, gvSIG, uDig etc) are available now a days (Anonymous, 2012)	The development of open source GIS software has –in terms of software history– a long tradition (Anonymous) with the appearance of a first system in 1978. Numerous systems are nowadays available which cover all sectors of geospatial data handling. The Geographic Information Systems (GIS) contributes significantly to VRT by allowing presentation of spatial data in the form of a map. In addition, GIS forms an ideal platform for the storage and management of model input data and the presentation of model results which the process model provides. Modern GIS technologies use digital information, for which various digitized data creation methods are used. GIS accuracy depends upon source data, and how it is encoded to be data referenced.
Differential Global Positioning System	A GPS receiver with differential correction (WAAS, Starfire, OmniStar, RTK, etc.) is usually used.	Differential Global Positioning System (DGPS) ensures doing the right thing, in the right place and at right time. The accuracy which is the important factor in VRT, demands for DGPS. The Global Positioning System (GPS) technology provides accurate positioning system necessary for field implementation of VRT. It provides position information of the locations in the field which is used by the control software to adjust rates based on prescription map. It provides the ability to spatially log the actual rates applied for the generation of as applied maps.
Computer	Remote Sensing data is processed and analyzed with computer software, known as a remote sensing application. A large number of proprietary and open source applications exist to process remote sensing data. A laptop, handheld computer or other computer system is used whereas some equipment manufacturers produce their own systems such as John Deere.	This component serves as two purposes the user interface and has the ability to run the application control software.
Software	GRASS GIS —Originally developed by the U.S. Army Corps of Engineers, open source is a complete GIS. A number of other softwares (like SAGA GIS, Quantum GIS, MapWindow GIS , gvSIG , uDig etc)are available for reading, analyzing the information to communicate desired application rates.	It reads the uploaded prescription map, analyses it and determine the desired application rate based on field position and logging. Further it communicates the desired application rates to the controller. According to an NOAA Sponsored Research by Global Marketing Insights, Inc. the most used applications among Asian academic groups involved in remote sensing are as follows: ERDAS 36 % (ERDAS IMAGINE 25 % & ERMapper 11 %); ESRI 30 %; ITT Visual Information Solutions ENVI 17 %; MapInfo 17 %. Among Western Academic respondents as follows: ESRI 39 %, ERDAS IMAGINE 27 %, MapInfo 9 %, AutoDesk 7 %, ITT Visual Information Solutions ENVI 17 %.

Table 3 Various Components of Variable Rate Technology (Continued)

Controller	It can be a separate system from the software and control mechanism.	It implements the set point rate communicated by the software and ensures that the control mechanism (motor or actuator) is putting out the appropriate rate. It also uses feedback from ground speed radar (GSR) or other speed sensor to compensate for speed variations while also using a speed or position feedback from the control mechanism to ensure it is turning at the appropriate speed or positioned correctly.
Hydraulic Motor and Valve	The metering unit can be controlled by a motor, linear actuator, or another control device.	The hydraulic motor uses a hydraulic control valve to adjust the flow rate to the motor thereby controlling speed of the motor.
Control and/or Metering Mechanism	An apron chain, seed disk, or liquid injection system	The feed rate is directly controlled by metering mechanism.

ability associated with all aspects of agricultural production for the purpose of improving crop performance and reducing environmental degradation/pollution. Variable rate technology combines a variable rate (VR) control system with application equipment to apply inputs at a precise time and/or location to achieve site specific application rates of inputs. Variable rate techniques results into increase in annual pasture production considerably, from 19,935 t DM yr^{-1} to between 21,239 and 24,798 t DM yr^{-1} when several variable rate application scenarios were compared with blanket application of fertilizer application was considered along with (Murray and Yule, 2007).

The earth's surface could have been described simply, if it were the same every where. The environment however, is not like that; there is almost endless variety (Webster and Oliver 1990). The spatial and temporal variability of soil fertility, weeds and diseases exist as intra and inter fields. This intra and inter-field variability may result from a number of factors (**Table 1**).

Variable Rate Technology requires information on spatial and temporal variability data on the Soil (soil texture, soil structure, physical condition, soil moisture, soil nutrients etc), crop (plant population, crop tissue nutrient status, crop stress, weed patches, insect or fungal infestation, crop yield etc) and climate (temperature, humidity rainfall, solar radiation, wind velocity etc.).

Assessment of Variability

Assessing variability is the critical first step in VRT, since it is clear that one cannot manage what one does not know. The processes and properties that regulate crop performance and yield vary in space and time. Adequately quantifying the variability of these processes and properties, and determining when and where different combinations are responsible for the spatial and temporal variation in crop yield is the challenge in VRT (Mullu and Schepers, 1997). A yield map defines the spatial distribution of crop yield but does not explain the observed variability. Imagery of crop growth and development over the growing season can uncover the cause-effect relationship that explains not only the yield variation within a field but also the magnitude of yield observed in a particular growing environment (Schepers *et al.*, 1996). For VRT agriculture to be useful, variation must be known of sufficient magnitude, spatially structures (on random) and manageable (Pierce, 1995). Maps form one basis for precision management: real-time management forms the other basis. Use of management maps is more common and these can be categorized as yield maps, condition maps, prescription maps and performance maps. Condition maps are measured and/or predicted using a broad array of technologies and techniques for estimating the spatial distribution of one or more properties of processes. Prescription maps are derived from one or more condition maps and form the basis for VRT (Sawyer, 1994). Performance maps record either input (fertilizers, pesticides, seed, energy etc. or outputs (crop yield and quality) and include derivatives of performance maps, such as profit maps (output-inputs). Various techniques for the assessment of variability are given in **Table 2**.

Components of Variable Rate Technology

VRT essentially comprises of eight components. The various components of variable rate technology are given in **Table 3**.

Implementation of Variable Rate Technology

The Variable Rate Technology can be implemented by three different approaches based on requirement and availability (**Table 4**). Among all these, the sensors are critical to success in the development of a VRT for three important reasons.

a) Sensors have fixed costs.
b) Sensors can sample at very small scales of space and time.
c) Sensors facilitate repeated measures.

The primary differences between

Table 4 Different Approaches of Variable Rate Technology Implementation

Type	Purpose	Reported Technology
Map Based	This is very common and popular approach for implementing VRA (variable rate application). In this approach a prescription map is generated based on soil analyses or other avaiable information and then used by the VRT to control the desired application rate. These maps can be generated using agricultural GIS software packages and can be either grid or zone-bases. The soil sample is usually named 'Farm Name –Field Name– Zone Name.' When soil analysis data is returned from the lab, the same naming convention is used; therefore allowing the GIS to match the data to the appropriate zone.	It can be implemented either by Zone-based maps which are created by automatically assigning a number to each zone within the field. These differential zones can be used for numerous applications, such as: variable rate fertilizer (broadcast and sidedress); plant growth regulators; cotton defoliants; seeding rates. It can also be implemented by grid sampling in which the area is arbitrary divided into grids using a desktop GIS or a PDA (handheld computer) loaded with an agricultural GIS software package. Each grid is assigned a number (Feature ID) which is comparable to the 'zone' column in case of zone based maps.
Sensor Based	In order to create sensor-based maps, most remote sensing systems expect to extrapolate sensor data in relation to a reference point including distances between known points on the ground. This depends on the type of sensor used. This type of system utilizes sensors to assess crop or field conditions to provide real time variable rate application (VRA) of inputs. Sensors are devices that transmit an impulse in response to a physical stimulus such as heat, light, magnetism, motion, pressure and sound. Sensors can be contact or remote, ground based or space based and direct or indirect. The sensor based approach attempts to more efficiently apply inputs by meeting crop requirement at the time of application to better meet real time crop needs.	Sensors have been developed to measure machinery, soil, plants, pests, atmospheric properties and water by sensing motion, sound, pressure, strain, heat, light and magnetism and relating these to properties such as reflectance, resistance, absorbance, capacitance and conductance. Several commercially available sensor-based, variable rate systems exist for efficiently managing inputs to maximize yields or returns.
Manual	Manual control can also be used to vary the application rates with the operator responsible for changing the rates on the controller during operation.	

map and sensor-based strategies are data analysis and interpretation. In the map-based approach the prescription map is prepared by using the historical information, typically gathered with yield monitors, soil testing, soil maps, and/or with data from sensors. The prescription map is than transferred to a variable rate applicator. A GPS receiver locates the applicator's position on the map and the rate is then adjusted based on the prescription map as the applicator moves across the field.

The sensor-based approach to precision agriculture uses sensors to measure crop and/or soil properties in real-time as the applicator moves across the field. Data from the sensor is collected, processed, and interpreted by an on-board computer which then sends a signal to a rate controller. One of the advantages of this approach is that the data is automatically analyzed and interpreted. The sensor information is directly converted to an application rate by a predetermined algorithm. This algorithm is typically constant at a field scale and often at the regional scale. However, one challenge associated with this approach is that the prescribed rate is constantly changing as the applicator moves across the field requiring the rate controller to respond quickly.

Applicability of Variable Rate Technology

Using sensor systems for variable rate application (VRA) is becoming more popular for cotton production. Three critical inputs for cotton production namely plant growth regulators, defoliants/boll openers and nitrogen can be very well monitored with the variable rate application technology.

Equipment

The equipment consist of sensors and control interface, a display and control module, and an application rate controller. Sensors can be used to measure soil or crop properties that are used to make in-season variable rate application to cotton.

Sensors and Vegetative Indices

Commercially available sensors operate above the crop and measure reflectance of different colors (wavelengths). The most common colors used for crop vegetation indices are red, near-infrared (NIR), green, and amber. Healthy, vigorous plants absorb red light and reflect near infrared light. The reflectance of these colors is used to calculate indices such as the Normalized Difference Vegetative Index (NDVI) or a simple ratio (RED/NIR). NDVI is determined from red and near infrared reflectance and is probably the most popular vegetative index. Other colors such as green or amber can be used in place of red when calculating NDVI. Though many vegetative indices can be used for VRA, only NDVI will be discussed for the remainder of this publication.

Research has shown that reflective indices such as NDVI measured at the correct growth stage can be highly correlated with cotton yield. While NDVI values can range from 0 to 1, values below 0.3 or above 0.9 are of little value in crop production. When NDVI is below 0.3, there is generally not much green in the field of view (i.e. more stubble, crop residue, or soil). Conversely, when values are greater than 0.9, everything in the field of view is green.

Prescriptions

Developing a sensor-based prescription happens in two steps. In the first step, the relationship between the plant property of interest and what the sensor measures are determined. In the second step, application rate is determined as a function of the sensor reading.

From a farmer or consultant perspective, the two steps that are outlined for developing prescriptions could be combined if the prescription is developed at the field level. Repeating this at various locations would yield a direct relationship between NDVI and the application rate. The maximum and/or minimum application rates can be pre defined so the system is restricted between these two application rates (i.e. if we feel that atleast 50 kg of nitrogen must be applied, so we set the lower limit at this rate). Then regardless of the prescription and sensor reading, the controller will not go below this rate. The same approach can be taken for the upper limit. These limits are established to ensure every part of the field receives some product, but that no part of the field receives excessive application of product.

Calibrating Equipment with Variable Rate Technology

Calibration of spreaders, planters, and sprayers is needed for uniform application, it is even more critical to calibrate VRT controlled equipment. The goal of calibration is to minimize application errors so that the target rates can be achieved with a certain level of confidence. The recommendations of the manufacturers must be kept in mind while calibrating equipment with VRT.

Expected Application Range

Prior to calibration of equipment with VRT, one must determine the range of planned application rates for the product (s) to be used during VR application. This range will be used to ensure that the software and hardware setup will properly operate over the expected range of rates once an acceptable setup is determined during calibration.

Pre-Calibration Checks

Make sure all hardware and software are in proper operating condition. Replace any worn hardware, especially those controlling the metering and distribution of material. Pre-calibration checks are different for different applicators.

Steps to be taken for Implementing VRT in India

In the present existent situation, the potential of VRT in India is limited by the lack of appropriate measurement and analysis techniques for agronomically important factors. High accuracy sensing and data management tools must be developed and validated to support both research and production. The limitation in data quality/availability has become a major obstacle in the demonstration and adoption of the variable rate technologies. The adoption of variable rate technologies needs combined efforts on behalf of scientists, farmers and the government. The following methodology could be adopted in order to operationalise precision farming in the country.

1. Creation of multidisciplinary teams involving agricultural scientists in various fields, engineers, manufacturers and economists to study the overall scope of variable rate technologies.

2. Formation of farmer’s co-operatives since many of the variable rate technologies tools are costly (GIS, GPS, RS, etc.).

3. Government legislation restraining farmers using indiscriminate farm inputs and thereby causing ecological/environmental imbalance would induce the farmer to go for alternative approach.

4. Pilot study should be conducted on farmer’s field to show the results of variable rate technologies implementation.

Creating awareness amongst farmers about consequences of applying imbalanced doses of farm inputs like irrigation, fertilizers, insecticides and pesticides.

Limitations of Variable Rate Technology

VRT has been mostly confined to developed countries. Reasons of limitations of its implementation in the developing countries like India are:

1) Small land holding 2) Heterogeneity of cropping systems and market imperfections. 3) Lack of technical expertise knowledge and technology. 4) India spends only 0.3 % of its agricultural gross domestic product in research and development. 5) High cost of technology. 6) No custom hiring operators.

Prospects of Variable Rate Technology

In India, major problem is the small field size. More than 58 percent of operational holdings in the country have size less than 1 ha. Only in the states of Punjab, Rajasthan, Haryana and Gujarat more than 20 % of agricultural lands have operational holding size of more than four hectare. There is a scope of implementing VRT for crops like rice and wheat especially in the states of

Punjab and Haryana. Commercial as well as horticultural crops also show a wider scope for precision agriculture in the cooperative farms.

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Studies on Development of Concentric Drum, Brush Type Ginger Peeler

by

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Abstract

A concentric drum brush type ginger peeler with a capacity to peel 7 kg per batch was developed. The nylon bristles to be used for peeling were optimized in another experimental setup using a semi mechanical ginger peeler. Nylon bristles of length 25 mm and thickness 0.7 mm were optimized for fixing in the inner wooden drum of the developed mechanical ginger peeler. Experiments on peeling ginger in a concentric drum brush type ginger peeler were conducted at varying drum loads (5, 6 and 7 kg) for various speeds of inner drum (35, 40 and 45 rpm), outer drum speeds of (20 and 25 rpm) and for varying peeling durations (5, 10 and 15 min). The optimum operating conditions for peeling ginger were obtained at drum load of 7 kg, for inner drum speed of 45 rpm, outer drum speed of 20 rpm and for the peeling duration of 15 min. The peeling efficiency was 61 % and the corresponding material loss was 5.33 %.

Introduction

Ginger, the rhizome of Zingiber officinale Roscoe is one of the most widely used spices of the family Zingiberaceae. India is one of the largest ginger producing countries in the world with an annual production of 831,607 tonnes from an area of 143,861 ha during 2008-09 (Spices Board, 2012).

Ginger when used as vegetable is harvested from sixth month onwards while for preparing dry ginger, the produce is harvested after eight months of planting when the leaves of the plant turn yellow and starts drying. The harvested clumps of ginger are cleaned manually to remove the dried roots and soil clods. The clumps are then broken to sufficiently large size rhizomes suitable for preparing dry ginger. After cleaning, the rhizomes are subjected to peeling. Peeling, in case of ginger is definitely an important unit operation where the fully matured rhizomes are scraped with bamboo splits having pointed ends to remove the outer skin before drying to accelerate the drying process. Deep scraping with knifes need to be avoided to prevent the damage of oil bearing cells which are present just below the outer skin. Excessive peeling will result in the reduction of essential oil content of the dried produce. The peeled rhizomes are washed before drying. The dry ginger so obtained is valued for its aroma, flavour and pungency (Balakrishnan, 2005).

A brush type ginger peeling machine with two continuous brush belts moving vertically in the opposite direction was reported by Agrawal *et al*. (1987). The maximum peeling efficiency of ginger obtained was 84.3 % at a belt speed of 85 rpm for belt spacing of 1 cm. Ali *et al*. (1991) reported the development of an abrasive brush type ginger peeling machine consisting of two continuous vertical belts provided with 32 gauge steel wire brush, 2 cm long and having a peeling zone of 135 cm, had a maximum peeling efficiency of 85 %. Singh and Shukla (1995) developed a abrasive peeler for potato and reported that the peel loss increased linearly with peeling time, drum speed and loading intensity. However, in case of increase in loading intensity of the peeler, this trend was not followed beyond 6 min of peeling. At higher batch loads, as the peeling continued beyond 6 min, some potatoes were over peeled and some were under peeled.

Presently the process of ginger peeling is done manually and the process is highly laborious. As this is an essential process to accelerate the drying process, the present study was undertaken with an objective to develop a mechanical peeler for ginger and to evaluate its peeling efficiency.

Materials and Methods

A brush type concentric drum ginger peeler provided with nylon bristles was developed at the College of Agricultural Engineering, Tamil Nadu Agricultural University, Coimbatore during 2009 for mechanical peeling of ginger. The peeler consists of two concentric drums (**Figs. 1** & **2**). The inner wooden drum of size 430 × 364 mm was provided with nylon bristles (25 mm long and 0.7 mm thick) for the entire length and the outer drum of size 470 mm × 550 mm was made of mild steel diamond cut mesh. Peeling of ginger was found effective when the inner and the outer drums rotated at varying speeds in the same direction. Variable speed was obtained by using four pulleys for power transmission. Two pulleys were provided on the central shaft on which the peeler drums were mounted and another pair was provided on an intermediate shaft. A handle of length 250 mm was provided at one end of the hollow shaft to rotate the inner drum manually. The entire unit was mounted on a water holding tank of size 820 mm long, 770 mm wide and 450 mm depth. Fresh ginger was fed in to the annular space between the inner and the outer drum through the opening provided in the outer drum. Peeling of ginger was caused by the abrasion of ginger against the drum surface.

Design of Shaft

A hollow galvanized iron shaft was used to mount the peeling drum. The diameter of the hollow shaft was determined using the following formula considering the fact that shaft for ginger peeling unit is subjected to bending and torsion only and the axial load acting on the shaft is zero (Khurmi and Gupta, 2006).

$$d_0^3 = \frac{16}{\pi[\tau]\left\{1-\left(\frac{d_i}{d_o}\right)^4\right\}} \times \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad \text{..................(1)}$$

where, d_0 is the diameter of the shaft, mm; P is the axial load, N; M_t is the twisting moment, N mm; M_b is the bending moment, N mm; $[\tau]$ is the design shear stress, N mm^{-2}; K_b is the combined shock and fatigue factor applied to M_b; Kt is the combined shock and fatigue factor applied to M_t; τ is the shear stress, N mm^{-2}; σ_b is the bending stress, N mm^{-2}; α is the column action factor.

For revolving shaft with gradual loading the values for K_b = 1.5, K_t = 1 and $[\tau]$ = 56 MPa = 56 N/mm^2.

Torque Transmitted to the Peeling Drum The peeling drum was manually operated. Considering the human energy as 0.1 hp (Sahay, 2006) the torque transmitted to the drum by manual rotation at maximum speed of 50 rpm was calculated by the following formula:

$hp = 2\pi NT_t / 60$ ....(2)

where, hp is the horse power transmitted to the peeling drum = 1 hp = (746 W), N is the speed of peeling drum, rpm, Tt is the torque transmitted, Nm.

Maximum rotational speed of the peeling drum (assumed) = 50 rpm

Hence, Torque tranmmitted = *(74.6 × 60) / (2 × 3.14 × 50) = 14.25 N m = 14,250 N mm*

Bending Moment of the Shaft The bending moment was calculated by considering the load acting on the drum. Assuming, Mass of the peeling drum = 20 kg, Mass of ginger to be peeled = 10 kg per batch, Total mass = 30 kg (or 300 N).

Fig. 1 Concentric drum brush type ginger peeler

The mass of the peeling drum and the ginger was considered as uniformly distributed load acting over a span length of 0.92 m. It was converted into equivalent point load acing at the centre of the shaft.

Considering the shaft as simply supported, the maximum bending moment occurs at the centre of the shaft and was calculated as (PSG, 1988):

$M_{b\ max} = PL / 4$ ....(3)

$M_{b\ max} = (300 \times 920) / 4 = 69{,}000$ N mm

Assuming d_0 / d_i = 0.82 and substituting all the values in **Eqn. 1**. d_0^3 is calculated as; d_0^3 = 17350.78

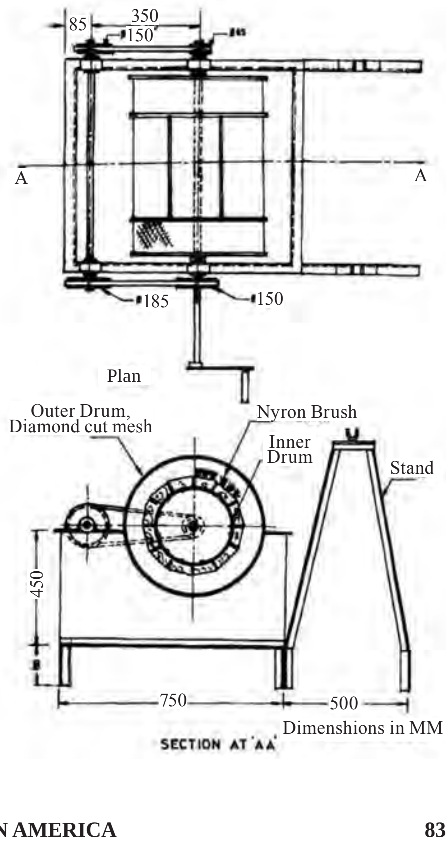
Hence, d_0^3 = 25.88 mm ≈ 26 mm

However, the shaft selected for the fabrication of the peeler was having an outer and inner diameter of 33 and 27 mm respectively and of length 1,540 mm.

Bush

Two bushes of 40 mm long, 27

Fig. 2 Plan and elevation of the ginger peeler



mm inner diameter and 33 mm outer diameter were welded at the centre of the drum cover on either side. The bush was reinforced with 3 numbers of spokes made of mild steel flats of size 230 mm long × 20 mm wide × 5 mm thick radiating from the centre towards the outer surface and welded on both the side covers.

V-block

A fabricated V- block made of mild steel flat of size 40 mm wide x 6 mm thick to a height of 40 mm rests on the outer frame of the water holding tank. The shaft with the drum was supported by the V-block.

Water Holding Tank

The water holding tank was fabricated from mild steel sheet of 20 SWG thick to a size of 820 mm long, 770 mm wide and 450 mm depth. The top of the tank was welded with a frame made of angle section of size 32 × 32 × 3 mm thick. The frame of the tank supports the V-block which in turn supports the shaft and the drum.

Handle

A handle of length 250 mm was provided at one end of the hollow shaft to rotate the drum manually.

Frame

Two 'A' shaped frames support made of mild steel flat of size 25 mm × 6 mm are fastened to the water holding tank by bolt and nut. Each A-frame is 50 mm wide at the top, 550 mm wide at the bottom with a height of 830 mm. On the top of each 'A' frame, V-block support of height 100 mm made of mild steel flat of size 25 × 6 mm are provided to rest the drum during unloading.

Drain Pipe

A mild steel drain pipe of 35 mm diameter is provided at the bottom of the tank and extended outside for removal of wash water.

Experiments on peeling of ginger in a concentric drum brush type ginger peeler were conducted at varying drum loads (5, 6 and 7 kg) for various speeds of inner drum (35, 40 and 45rpm), outer drum speeds of (20 and 25 rpm) and for varying peeling durations (5, 10 and 15 min). Freshly harvested fully matured ginger available from the local market was used for the experimental study. All the experiments were replicated thrice. Completely

Table 1 Specifications for manually operated concentric diamond cut mesh drum brush type peeler

Components	Specifications
Outer drum	
Material	Mild steel diamond cut mesh
Holding capacity	7 kg
Length	470 mm
Diameter	550 mm
Mesh size	32 × 12 mm
Side covers	Mild steel sheet 20 SWG thick
Inlet opening	170 × 230 mm
Door	170 × 230 mm
Inner drum	
Material	Wood
Length	430 mm
Outer diameter	364 mm
Drum shaft	Mild steel pipe of size 430 × 33 × 3 mm
Circular frame for fixing reaper	Mild steel flat of size 25 × 5 mm
Diameter of circular frame	254 mm
Wooden reapers	430 × 60 × 30 mm
Number of wooden reaper	30 Nos.
Nylon bristles	
Length	25 mm
Thickness	0.70 mm
Shaft	
Material	Galvanized iron pipe
Length	1250 mm
Outer diameter	33 mm
Inner diameter	27 mm
Intermediate shaft	
Length	1250 mm
Diameter	25 mm
Pulleys for power transmission	
Number and type	4 Nos. of A-type pulleys
Optimum diameters	d_1 = 65, d_2 = 150, d_3 = 170 and d_4 = 150 mm
Bearings	
Material	Gun metal
Diameter	27 mm
Numbers	2
Belt for power transmission	Perforated A-type belt
Handle	
Material	Mild steel flat of size 25 × 3 mm
Length	250 mm
Water holding tank	
Material	Mild steel sheet 20 SWG thick
Size	820 × 770 × 450 mm
Top end support	Mild steel L-angle of size 32 × 32 × 3 mm
Drain pipe	
Material	Mild steel pipe
Size	Diameter of 35 mm

Randomized Block Design was adopted to analyze the significance of the independent variables using statistical AGRES (Version 7.01) and regression analysis was done by Essential Regression (version: 2.21) softwares.

Quality

The quality of peeled ginger was evaluated in terms of the peeling efficiency and the material loss as described by Ali *et al.* (1991).

$$\eta_p = [(W_{TS} - W_S) / W_{TS}] \times 100 \quad \ldots (4)$$

$$ML = \{[(W_1 - W_{TS}) - (W_2 - W_S)] / W_1\} \times 100 \quad \ldots (5)$$

where, η_p is the peeling efficiency of ginger peeler (%), ML is the material loss of ginger (%), W_{TS} is the theoretical weight of skin on fresh ginger (g), W_s is the weight of skin removed by hand trimming after mechanical peeling (g), W_1 is the total weight of ginger before peeling (g), W_2 is the total weight of ginger after mechanical peeling (g).

Results and Discussion

A concentric drum brush type ginger peeler was fabricated with the design specifications detailed in **Table 1**.

Effects of Drum Speed and Peeling Duration on Peeling Efficiency

It was observed that as the outer drum speed increased from 20 rpm to 25 rpm, the peeling efficiency increased with the increase in peeling duration for increase in all inner drum speeds studied (35, 40 and 45 rpm) at a constant drum load of 6 kg. A maximum peeling efficiency of 62.86 % was obtained when the outer drum speed was 25 rpm, the inner drum speed was 45 rpm and the peeling duration was 15 min at a constant drum load of 6 kg of ginger (**Fig. 3a**).

Effects of Drum Speed and Peeling Duration on Peeling Efficiency

At a constant outer drum speed of 20 rpm, as the inner drum speed increased from 35 rpm to 45 rpm, at a given load of 6 kg and peeling duration of 15 min, the peeling efficiency increased from 48.63 to 62.86 %. At inner drum speed of 45 rpm and drum load of 6 kg as the peeling duration increased from 5 min to 15 min the peeling efficiency increased from 37.92 % to 62.86 % (**Fig. 4a**).

Peeling efficiency decreased from 63.12 % to 61.43 % when the drum load increased from 5 kg to 7 kg at inner drum speed of 45 rpm and peeling duration of 15 min. At a constant drum load of 6 kg and at the inner drum speed of 45 rpm as

Fig. 3a Peeling efficiency for various inner

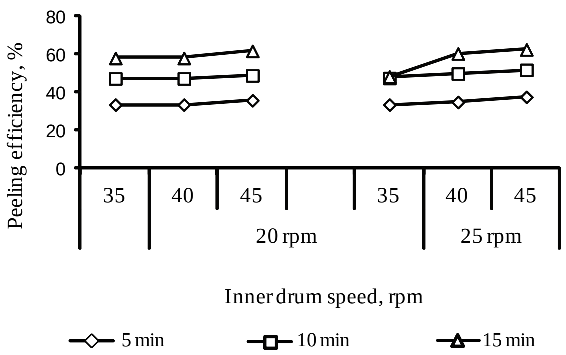


Fig. 3b Material loss for various and outer drum speeds inner and outer drum speeds

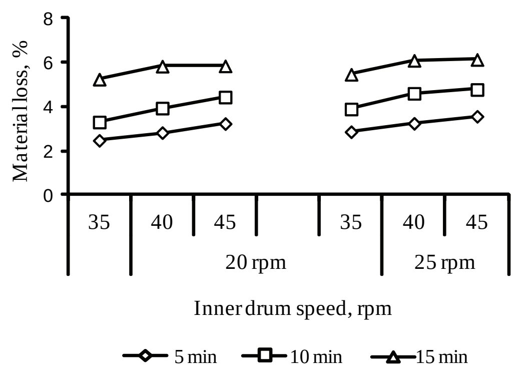


Fig. 4a Peeling efficiency for various inner speeds

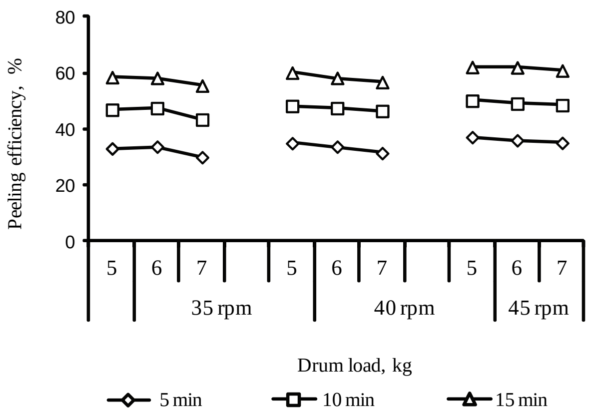
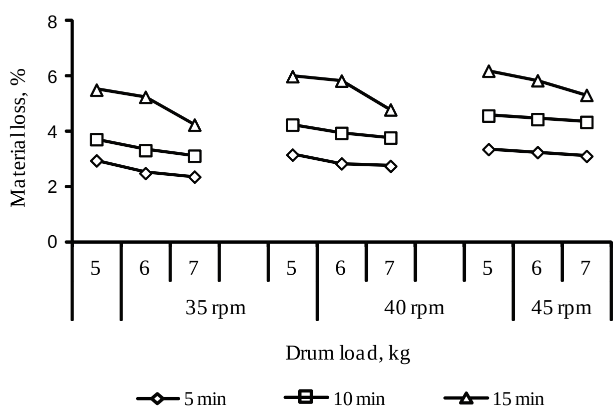


Fig. 4b Material loss for various inner drum and drum loads speeds and drum loads



the peeling duration increased from 5 min to 15 min, the peeling efficiency increased from 37.92 % to 62.86 % (**Fig. 5a**).

It was observed that increase in peeling duration increased the peeling efficiency. The peeling efficiency also increased with increase in the speed of inner drum but it however decreased with increase in drum load. Analysis of variance showed a significant ($p < 0.01$) influence of the independent variables on the peeling efficiency of ginger in the mechanical peeler but no significant influence was observed for their interactions.

Effects of Drum Speed and Peeling Duration on Material Loss

It was found that at a given drum load, as the outer drum speed increased from 20 rpm to 25 rpm, the material loss increased with the increase in peeling duration and for the increase in the speeds of inner drum i.e. 35, 40 and 45 rpm (**Fig. 3b**). A maximum material loss of 6.15 % was observed when the outer drum speed was 25 rpm, the inner drum speed was 45 rpm for the peeling duration was 15 min when the drum load was constant at 6 kg of ginger. It was further observed that for all the cases of higher outer drum speed, the material loss was higher and hence 20 rpm of outer drum speed was considered as optimum.

Effects of Drum Speed and Peeling Duration on Material Loss

At a constant outer drum speed of 20 rpm, as the inner drum speed increased from 35 rpm to 45 rpm, at a given load of 6 kg and peeling duration of 15 min, the material loss increased from 5.26 to 5.86 %. At inner drum speed of 45 rpm and drum load of 6 kg as the peeling duration increased from 5 min to 15 min the material loss increased from 3.25 % to 5.86 % (**Fig. 4b**).

Material loss decreased from 6.21 % to 5.33 % when the drum load increased from 5 kg to 7 kg at inner drum speed of 45 rpm and peeling duration of 15 min. At a constant drum load of 6 kg and at the inner drum speed of 45 rpm as the peeling duration increased from 5 min to 15 min, the material loss increased from 3.25 % to 5.86 % (**Fig. 5b**).

It was observed that increase in peeling duration increased the material loss. The material loss also increased with increase in the speed of inner drum but it however decreased with increase in drum load. Analysis of variance showed a significant ($p < 0.01$) influence of the independent variables on the material loss of ginger in the mechanical peeler but no significant influence was observed for the interaction of the independent variables.

Agrawal *et al.* (1987) reported a material loss of 5.1 % at the maximum peeling efficiency of 84.3 % in a vertical brush type ginger peeling machine when the belt speed was 85 rpm and belt spacing was 1 cm. Ali *et al.* (1991) reported a material loss of 3.27% in an abrasive brush type ginger peeling machine when the peeling efficiency was 85.56 %.

The relationship between peeling efficiency (η_P) and material loss (ML) with the variables like drum load (M_P), inner drum speed (S_i), outer drum speed (S_o) and peeling duration (t_p) in a concentric drum brush type ginger peeler was predicted by multiple regression models as follows:

$$\eta_P = 7.275 - 1.551\, M_P + 0.406\, S_i + 0.353\, S_o + 2.529\, t_p \quad (R^2 = 0.93) \qquad (6)$$

$$ML_P = -1.263 - 0.341\, M_P + 0.083\, S_i + 0.078\, S_o + 0.255\, t_p \quad (R^2 = 0.97) \qquad (7)$$

Eqn. 6 shows that peeling efficiency was in positive correlation with peeling duration, inner drum speed, outer drum speed and in negative correlation with the drum load. The coefficients of the independent variables, indicated that the influence of peeling duration was the highest followed by drum load, inner drum speed and outer drum speed. From the **Eqn. 7**, it is observed that the material loss was in positive correlation with the peeling duration, inner drum speed, outer drum speed and in negative correlation with the drum load.

Fig. 5a Peeling efficiency for various inner speeds

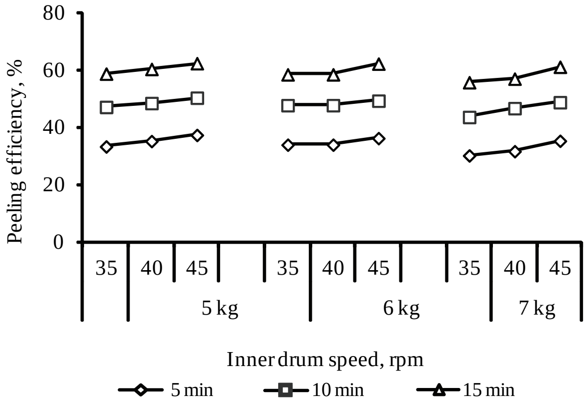
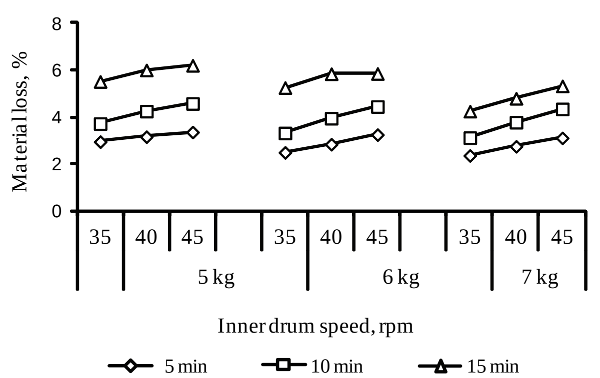


Fig. 5b Material loss for various inner speeds and drum loads and drum loads



Optimization of Machine Parameter for Peeling

The process of peeling in a concentric drum brush type ginger peeler was optimized for the conditions at which the peeling efficiency was maximum and the material loss was minimum. Considering these factors it could be found that maximum peeling efficiency of 61 % with corresponding material loss of 5.33 % when the drum load was 7 kg, at an inner drum speed of 45 rpm, outer drum speed of 20 rpm and for peeling duration of 15 min.

Conclusions

1. A concentric drum brush type ginger peeler with a capacity to peel 7 kg of ginger per batch was developed.

2. To accelerate the process of peeling, nylon bristles of length 25 mm and thickness 0.7 mm were fixed in the inner wooden drum of the developed mechanical ginger peeler.

3. The optimum operating conditions for peeling of ginger was obtained at drum load of 7 kg, for inner drum speed of 45 rpm, outer drum speed of 20 rpm and for the peeling duration of 15 min.

4. The maximum peeling efficiency obtained in the peeler was 61 % and the corresponding material loss was 5.33 %.

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EVENT CALENDAR

◆ **EuroTier 2014**
November 11-14, 2014, Hanover, GERMANY
http://www.eurotier.com/home-en.html

◆ **EIMA International 2014**
November 12-16, 2014, Bologna, ITALY
http://www.eima.it/en/index.php

◆ **Agromek and NJF Joint Conference** —Future Arable Farming and Agricultural Engineering—
November 24-25, 2014, Herning, DENMARK
http://www.njf.nu/site/seminarRedirect.asp?intSeminarID=477 &p=1004

◆ **KISAN 22nd Fair**—India`s Largest Agri Show —
December 10-14, 2014, Pune, INDIA
http://pune.kisan.in/

◆ **ICoME-2014**—the 5th international conference on mechanical Engineering—
December 17-19, 2014, Chiang Mai, THAILAND
http://me.eng.kmitl.ac.th/icome2014/

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

◆ **GFIA**—Global forum for innovations in agriculture—
March 9-10, 2015, Adnec, ABU DHABI
http://www.innovationsinagriculture.com/

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

◆ **XXXVI CIOSTA CIGR V Conference 2015**
May 26-28, 2015, Saint-Petersburg, RUSSIA
info@ciosta2015.org.

◆ **10th ECPA Meeting**—Conference theme: Precision agriculture for efficient resources management under changing global conditions—
July 12-16, 2015, ISRAEL

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

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

◆ **10th European Conference on Precision Agriculture**
July 12-16, 2015, Volcani Center, Israel
http://www.ecpa2015.com/#!call-for-papers/c1cyg

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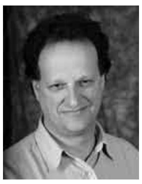
NEWS

Congratulations!

2014 ASABE and CSBE/SCGAB Annual International Meetings were jointly held at Montreal Convention Center, Montreal, Canada from July 13th to 16th, 2014. Although there exist many foundations and associations on agricultural engineering in the world, ASABE is one of the biggest and is actively participated by students, professors, researchers, manufacturers, engineers and related parties from all over the world. To accelerate their professional activities, various awards were given every year.



Dr. Bernard Panneton

[CSBE] Maple Leaf Award

Maple Leaf Award is given to honor 10+-year CSBE members whose work outstands for their personal qualities, society activities and professional abilities. This is the highest award by the Society.

Dr. Bernard Panneton is the recipient of the 2014 CSBE-SCGAB Maple Leaf Award in recognition of his outstanding contributions to engineering for agricultural, food and biological systems. He has worked for more than 25 years as a research scientist for the Horticultural Research and Development Center (Agriculture and Agri-food Canada) in Quebec. In addition, he has also worked as adjunct professor at Laval University in the departments of Agricultural Engineering, Plant Science and Mechanical Engineering and at Universite de Sherbrooke in the MSc program in Environmental Studies. His main research areas are engineering for plant protection, applied spectroscopy, precision agriculture and data analysis. He was granted two patents on sprayer technology that reduced the environmental impact.

Dr. David D. Jones

[ASABE] Massey-Ferguson Educational Gold Medal Award

Massey-Ferguson Educational Gold Medal Award is given “to honour those whose dedication to the spirit of learning and teaching in the field of agricultural engineering had advanced our agricultural knowledge and practice, and whose efforts serve as an inspiration to others.” It is established in 1965, the endowed award is named for Daniel Massey, pioneer Inventor and agricultural machinery manufacturer, and Harry Ferguson, inventor and Ardent exponent of agricultural mechanization.

Dr. David D. Jones is an associate dean for undergraduate programs, College of Engineering, professor, Department of Biological Systems Engineering, University of Nebraska-Lincoln. He has developed the new UNL biological systems engineering curriculum in addition to an agricultural engineering curriculum, and this co-existence and co-development of the curricula has provided mutual benefit and became a model for co-curricular improvement. Also, to enhance the quality, quantity and success of students transferring from Nebraska community colleges into the UNL College of Engineering, he has worked extensively to deliver and develop course material for engineering education at all levels. He has taught various courses and served as an advisor to numerous MS and PhD students.

Dr. Suat Irmak

[ASABE] John Deere Gold Medal Award

In 1837, John Deere forged a piece of saw blade into a plowform, creating the world’s first all-steel moldboard. A century later, his descendants established the John Deere Award to recognize “Distinguished Achievement in the Application of Science and Art to the Soil.”

Dr. Suat Irmak is the recipient of the 2014 John Deere Gold Medal Award. He is a professor at Department of Biological Systems Engineering, University of Nebraska- Lincoln contributing to the soil and water resources engineering profession: he is well recognized for his exemplary accomplishments in the application of science- and research-based information to educate farmers, crop consultants, and state and federal personnel in enhancing the efficiency of sprinkler irrigation practices to improve crop water productivity, minimize losses, and reduce water and energy use in agriculture. In addition to his work at the university, he has developed UNL’s South Central Agricultural Laboratory, and has been providing leadership to the Nebraska Agricultural Water Management Network, and the Nebraska Water and Energy Flus Measurement, Modeling, and Research Network. His research findings are being utilized by farmers, crop consultants, researchers, state and federal agencies, irrigation industry and other private companies in the development of management guidelines.

NEWS

Dr. Lalit R. Verma

[ASABE] James R. and Karen A. Gilley Academic Leadership Award

James R. and Karen A. Gilley Academic Leadership Award is given to an ASABE member who is currently providing outstanding academic leadership while serving as the department head/ chair of a Biological and Agricultural Engineering Department in the United States. It was established in 2011 and is being endowed by ASABE Fellow, Dr. James R. Gilley, his wife Karen and family.

Dr. Lalit R. Verma, the current president of ASABE, is the recipient of the 2014 James R. and Karen A. Gilley Academic Leadership Award. He is currently professor and head, Department of Biological and Agricultural Engineering, at the University of Arkansas, and previously at Louisiana State University. Based on his leadership in the development and promotion of biological engineering as a science-based discipline, he coordinate the transformation of small and unsustainable agricultural engineering programs at the universities into vibrant and growing pragmas by providing leadership in the development of skill competencies and accreditation criteria. At the University of Arkansas, he established two separate departments, biological and agricultural engineering and biomedical engineering programs. Dr. Verma is internationally recognized for his research in rice and forage post-harvest engineering and technology.

Mr. Allen Myers

[ASABE] Cyrus Hall Mccormick Jerome Increase Case Gold Medal Award

Cyrus Hall McCormick, inventor of the self-rake reaper, and Jerome Increase Case, developer of the reliable threshing machine are commemorated with this Gold Medal award, and this award is given “For Exceptional and Meritorious Engineering Achievement in agriculture” and established in 1932.

Mr. Allen Myers is the recipient of the 2014 Cyrus Hall McCormick Jerome Increase Case Gold Medal Award. He is a president at Ag Leader Technology, Inc., Ames, Iowa and is recognized as the father of yield monitoring. His device is the most widely used yield monitor for grain combines in the world: it has been said that he has changed the face of world agriculture through development of affordable and robust yield monitoring technology for agricultural combines. He also continues to pursue innovation through the development of new product lines for aftermarket and OEM use that help optimize agricultural production by managing the spatial metering and placement of inputs to crop production systems. Committed to education and research, he has supported development of the precision agricultural lab in the agricultural and biosystems engineering department at Iowa State University. In addition, Ag Leader promotes better learning opportunities: offering on-the job training, equipment and software to teaching programs in precision agriculture, five half-time tuition scholarships annually, and internships and student employment opportunities to ISU graduates. His work has received 12 patents.

Dr. Digvir S. Jayas

[ASABE] Kishida International Award

The Kishida International Award, started in 1978, is to “recognize outstanding contributions to engineering mechanization-technological related programs of education, research, developments, consultation or technology transfer outside the United States.” It is endowed by Shin-Norinsha Co., Ltd. of Japan- publisher of Agricultural Mechanization in Asia, Africa and Latin America and other publications in honour of Yoshikuni Kishida, founder of the firm.

Dr. Digvir S. Jayas is the recipient of the 2014 Kishida International Award. He is currently a vice president (Research and International) and a distinguished professor at University of Manitoba, Winnipeg, Manitoba, Canada. For more details about Dr. Digvir S. Jayas, please refer to the AMA, Vol.45 No.3, p.21.

ABSTRACTS

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

1250: Studies on Direct Seeded and Transplanted Rice Based Cropping Systems and Their Subsequent Effect on Productivity, Energy Dynamics and Soil Fertility in Upper Gangetic Plains of India: V. P. Chaudhary, Project Directorate for Farming Systems Research (ICAR), Modipuram 250 110, Meerut (UP), INDIA; **D. K. Pandey**, same; **B. Gangwar,** same.

ABSTRACTS

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

A field study was conducted during 2003 to 2006 at Project Directorate for Farming Systems Research, Modipuram, India to study the effect of crop establishment methods on productivity of hybrid rice and subsequent crops wheat, chickpea, mustard and soil fertility in rice based Farming system. The five rice crop establishment methods namely direct seeding (dry bed), drum seeding (wet bed), mechanical transplanting (puddled), mechanical transplanting (unpuddled) and manual transplanting (puddled) in main plot and wheat, chickpea and mustard in sub plot were tested in split plot design with four replications. The highest crop productivity of hybrid rice (8.52 t ha^{-1}) was obtained with drum seeding (wet bed) while direct seeding (dry bed) recorded the maximum productivity of wheat (5.70 t ha^{-1}), chickpea(2.20 t ha^{-1}) and mustard (1.86 t ha^{-1}).Similarly, greater system productivity in terms of rice equivalent yield (15.26 t ha^{-1}), system net returns (US$ 1,120 ha^{-1}), and production efficiency (41.81 kg ha^{-1} day^{-1}) except land use efficiency (75.62 %) in rice -wheat system. The fertilizer consumed the highest input energy about 42 to 45 % of total input energy use followed by 21 to 25 % in irrigation, 11 to 18 % in land preparation, 9 to 10 % in seed & sowing and 2 to 3 % in interculture/ weeding in rice-wheat system. However, it was consumed 40 to 44 and 50 to 54 % in fertilizer, 18 to 24 and 18 to 22 % in irrigation, 9 to 11 and 5 to 7 in seed & sowing and 3 to 4 % in both interculture/ weeding in rice-chickpea and rice- mustard system, respectively. The net return energy of the system was found to be high in drum seeded (170,926 MJ/ha) followed by direct seeded (169,070 MJ/ha) and lowest was 150,542 MJ/ha in manually transplanted (puddled). The similar pattern of energy was also found in rice- mustard and rice- chickpea systems. The soil analysis after 3 crop cycles indicated that soil organic carbon increased positively by 6.12 % over initial status in rice -chickpea system. Available N and K balances were generally positive in rice crop establishment methods and all the subsequent crops. P balances were positive in transplanting under rice -chickpea crop sequence followed by rice -mustard and rice -wheat cropping sequence. This study suggested that drum/ direct seeded rice based cropping systems not only produced higher grain yield of hybrid rice but also resulted in greater productivity of subsequent crops i.e. wheat, chickpea, mustard, profitability, energy use and soil fertility.

1257: Physical and mechanical properties of different size of Onion (Allium Cepa L.): Vijaya Rani, Assistant Professor, Department of Farm Machinery and Power Engineering, Haryana Agricultural University, Hisar, INDIA; **A. P. Srivastava**, National Coordinator (NAIP), ICAR, 319 KAB -II, Pusa Campus, New Delhi, INDIA.

The physical and mechanical properties of onion were determined which would be very much essential for the design of components namely, capacity and slope of hoppers, length and type of conveyors, type of grading mechanism of certain grid size, type of cutter and force required by cutter of different machineries to be used as onion harvesters, detoppers and graders. The onion crop, variety NP53 was harvested at maturity along with leaves to determine the properties for three size of the onion bulbs viz., small (less than 63.5 mm), medium (63.5 to 76.2 mm) and large (greater than 76.2 mm). The overall mean moisture content of top and bulb, equatorial diameter, polar diameter, diameter at neck, length of longest leaf, number of leaves, weight with leaf and bulk density was 86.05 %, 73.59 %, 53.46 mm, 47.19 mm, 13.78 mm, 308.47 mm, 10, 71.90 g and 0.24 g cc^{-1}, respectively. The per cent of onions found to be oblate was 70 and prolate 30. The mean shape factor was 1.12. The shape of the onions may be considered spherical to oblate. The mechanical properties determined were, coefficient of static friction required for determining slope of various components and shearing strength required to cut the top and the values found were 0.41 and 18.71 kgf.

1350: Mapping Plant Water Content by Aster High Resolution Satellite Imagery in Irrigated Wheat: Adel H. Elmetwalli, Department of Agricultural Engineering, Faculty of Agriculture, Tanta University, Tanta, EGYPT; **Andrew N. Tyler**, School of Biological and Environmental Sciences, University of Stirling, Stirling, FK9 4LA, UK.

Mapping plant water content (PWC) by means of earth observation provides the opportunity for understanding and characterising plant water status of crops at a regional scale and enable more efficient irrigation management. The overall aim of this investigation was to assess the potential of ASTER high resolution satellite imagery to map regional PWC variations in irrigated wheat in the Nile Delta of Egypt. Vegetation indices, NDVI, RVI, GNDVIbr and NDWI, were derived from ASTER imagery to relate them to PWC. The results demonstrated that PWC variation of wheat crops can be detected using ASTER high resolution satellite images through the derived vegetation indices. The SWIR radiation of the electromagnetic spectrum centred at 1,656 nm showed high sensitivity to PWC and thus NDWI based on this region demonstrated the best relationships with PWC ($R^2 = 0.74$). The results therefore demonstrate the feasibility of using high resolution satellite images, including ESA's forthcoming GMES Sentinel 2, to give a better understanding of crop water status at a regional scale. ■■

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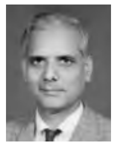
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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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

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

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

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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.
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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.
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AMA - AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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