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VOL.45, No.3, SUMMER 2014

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YOSHISUKE KISHIDA

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EDITORIAL

The current world population is approximately 7.2 billion, and it continues to increase by 70 to 80 million every year. Even though Japan sees decrease in population with the growing number of elderly, the population is increasing in the majority of the world and it is estimated to reach 9 billion by 2050. Human beings are a part of the organism, and they exist in the life system. When the life system, the organism excluding human beings, is damaged in any ways, this damage would risk human lives.

It is said that the source of the world ecological system is microorganism. Most microorganism lives within 10 centimeters down the ground, thus the fertility of forest soil is rich. More than 7 million hectares of this rich forest is disappearing every year because of human economic activities even though they try to plant trees. It is essential to maintain the forest in the perspective of the life system, especially to maintain the biodiversity. There are various reasons why forest is disappearing. In Japan, for example, when the government liberalized forest products approximately 50 years ago, business firms went to South East Asia and cut trees with cheap local labour. A while ago, 60 % of the Filipino land was forest, but currently it is less than 15 % and Philippine imports lumber. Japan also imports cheap lumber so that many Japanese forest industries bankrupted and those villages engaged in the industry disappeared. The developing countries such as Africa cut trees for fuel. In fact, more than half of the lumber is used for fuel. In some places trees are replanted, but in others the biodiversity is lower. Humans need to live in harmony with the life system, but unfortunately it is true that humans are destroying the life system which is protecting them. Cutting trees depletes water resource and thus the nutrition of the soil gets poorer.

Approximately 900 million people are suffering from hunger and majority of them live in the areas with deteriorated soil. Also, human business activities increase carbon dioxide that leads to global warming. The decrease in forest and global warming began to affect the organism in the ocean. The environment surrounding human beings will be harsh when considering food production. In this harsh condition, the food production is needed to increase. What is the most important to increase the food production is precise and precision operation. This operation can be carried out only by farm mechanization. The development of agricultural machinery can help higher food production and can feed more people. The appropriate machines are required depending on the characteristics of the soil and growing plants. The development of agricultural mechanization would not be the same in all over the world. Thus, the industries are needed to design and produce the appropriate machines. Currently the structure of the industry contains a few manufacturers of engines, tractors and combines and many small, medium-size manufacturers. The survival of small local manufacturers in this field, backed-up by technical and scientific information from the world is utmost necessary.

The most important in farm machinery is said to be artificial intelligence which can maintain machines. Google Inc. announced to commercialize self-driving car by 2020. Moreover, Amazon.com, Inc. announced miniature helicopter drones to deliver the packages. When thinking about the agricultural mechanization, informatization is a key. What farm machines need to do should depend on the system providing the necessary information. When developing agricultural machinery in the world including the developing countries, how to establish this system is highly significant. The enactment and maintenance of the system of farming and farm machines need to be carried out.

Yoshisuke Kishida
Chief Editor

July, 2014

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Development and Evaluation of Palmyrah Tree Climbing Device

by

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Abstract

Skilled workers are engaged in climbing palmyrah tree for harvesting nuts, crown cleaning and neera collection. Difficult in getting the services of skilled palmyrah climbers in time and their high wages, accident risk factors are perceived as important constraints in profitable palmyrah cultivation. For ensuring safety in tree climbing and to encourage even unskilled palm workers into climbing the tall tree, a palmyrah tree climber with safety features has been developed. The device has a set of upper and lower frames, which are alternately used to grip the tree for climbing up or down. The upper frame of tubular construction has a seat, side rails and a back support. The safety features viz., adjustable and pivotable seating arrangement, improved configuration of tree holding section, side support in any direction, safety rope and turn buckle mechanism enhance safety and comfort of the user. The performance of palmyrah tree climbing device was evaluated in terms of safety, comfort, output, saving in cost and time of operation and compared with conventional method. The use of palmyrah tree climbing device enhanced the comfort of the workers with 28-29, 36-43 and 36-37 percent reduction in energy expenditure, overall discomfort rating (ODR) and body part discomfort score (BPDS) respectively. Also it resulted in three and four fold increase in the safety and ease of operation respectively when compared with conventional method for neera tapping and fruit harvesting operations. Though the capacity of palmyrah tree climbing device with safety features for harvesting fruit bunches and tapping neera was lower than the conventional method, it resulted in alleviation of acute skilled labour constraints in palmyrah cultivation with enhanced safety and comfort. The cost of fruit bunch harvesting and neera tapping operation using palmyrah tree climbing device with safety features is comparable.

Introduction

Climbing techniques of palmyrah palm is similar to that of coconut palm. Two basic techniques used for climbing palm trees are front foot technique and frog technique. The front-foot technique used by the workers to climb palmyrah tree is very similar to rock climbing. The accessories employed by the worker viz., a ladder, a pair of gripping aids for upper and lower part of the body, a basket for holding the knife, a wooden tongs/stave and containers for the lime and for collecting the sap from the tree. Skilled workers are engaged in climbing palmyrah tree for harvesting nuts, crown cleaning and neera collection. Due to various socio-economic factors, the number of such traditional skilled palm climbers is steadily declining. It was a challenge to the technology developers to fabricate a simple, safe and easy to use device for climbing palmyrah tree, which could even be operated by an unskilled person.

Methods and Materials

The sequence of operations carried out by the worker after reaching the top of the tree for neera tapping as shown in **Fig. 1** is anchoring his body on the tree trunk with the help of the gripping aids, transferring the sap form the clay pot fitted with the inflorescence to a container carried on the back of his body, slicing the

male/female inflorescence using the knife, pressing and stroking the male/female inflorescence with the help of wooden tongs/stave for softening the tissue, applying lime inside the clay pot with a brush, fitting the clay pot back on the inflorescence stalk, moving around the tree and repeating the above sequence of operations for all the matured inflorescence and cleaning the crown of the tree.

The sequence of operations carried out by the worker after reaching the top of the tree for harvesting fruit bunch is tying a pair of adjacent bunches with the coir rope, cutting the stalk of the fruit bunch with knife, lowering the bunch to the ground level with the help of rope or tying the harvested bunches with hip, moving around the tree and repeating the above sequence of operations for all the matured fruit bunches and descending the tree with fruit bunches as shown in **Fig. 2**.

After completion of the operation at the top of the tree, the worker descends. For descending, he lowers his hands one by one behind the trunk with aid and just lets the sole of his feet with the aid drag against the tree. While descending, he carries the weight of neera or fruit bunches on his back.

The technique of gripping the tree with both hands and feet, using gripping aids and then pushing up the body to climb higher, results in intermittent pressure over the soles and palms leading to thickening of skin in palms,, legs and shoulder of the worker. In response to friction, there is steady rate of increase in epidermal turnover, and laying down of thickened vertically oriented collagen bundles in papillary dermis, resulting in lichenfication in fore arms as shown in **Fig. 3**. The other health hazards associated with palmyrah tree climbing include slip during rainy days and insect bite. Carrying the accessories viz., ladder (12 kg) and ascending the palmyrah tree with a basket for holding the knife (1.2 kg), a set of gripping aids (1.4 kg) and containers for collecting the sap (0.4 kg) from the tree and

Fig. 1 Unit operations involved in neera tapping

Transfering neera from clay pot to the container

Slicing the inflorescence

Pressing the inflorescence with wooden tongs

Applying lime inside the clay pot

Fitting the clay pot

Cleaning the crown of tree

Fig. 2 Unit operations involved in fruit bunch harvesting

Tieing, harvesting and dropping the fruit bunch from tree top to the ground

Harvesting and tieling the fruit bunch with hip

Descending with the fruit bunch tied to the hip

for the lime (0.04 kg), descending with an additional weight of neera (5-10 kg minimum per tree) results in lower back pain and musculoskeletal disorders.

Hence for minimizing drudgery of the arecanut plantation workers with increased safety at reduced human energy expenditure level, a palmyrah tree climbing device with safety features has been developed. The developed device has a set of upper and lower frames, which are alternately used to grip the tree for climbing up or down (**Fig. 4**). The upper frame of tubular construction has a seat. It has an adjustable/ detachable 'U' member between which and the main frame, the tree is gripped. The user sits comfortably on the seat facing the tree, the force of which grips the tree quite firmly. The lower frame is also constructed similarly, but lighter in weight and has a provision for the operator to hold it with his toes. The worker first sits on the upper frame and pulls the lower frame up with his legs. Then he puts his weight on the lower frame, stands on it and pulls up the upper frame. This action is alternated and the climbing is executed. The device can be adjusted to accommodate the small range of variations in the palm tree's girth with turn buckle mechanism. However the diameter of a typical palmyrah near the ground and up to a height of 3 m being quite huge, the developed device cannot be accommodated in this part of the tree. So, similar to the ladder/device that a traditional climber uses, an aluminium ladder of 3 m height has been provided along with the climbing device. This ladder has a hoop to lock itself to the tree as well as a foldable top, on which the climbing device can be positioned and clamped on the tree for the operator to climb on to it (**Fig. 4**). The specifications of Palmyrah tree climbing device with safety features are furnished in **Table 1**.

The performance evaluation of palmyrah tree climbing device with safety features is compared with conventional method for harvesting fruit bunches and tapping neera. The physiological stress imposed on the worker for ascending, neera tapping/fruit bunch harvesting and descending palmyrah tree operations viz., heart rate (beats per min^{-1}) and energy consumption of work (kJ min^{-1}). The heart rate and oxygen consumption rate was recorded using computerized ambulatory metabolic measurement system (K4b2). The discomfort experience by the worker was assessed interms over all discomfort rate (ODR) and

Fig. 3 Health hazards associated with palmyrah tree climbing

Thickening of skin in palms of palmyrah tree climber

Thickening of skin in legs of palmyrah tree climber

Thickening of shoulder of palmyrah tree climber

Lichenfication (Occupational dermatosis) in forearms of palmyrah tree climber

Additonal weight carried by the worker Ladder, Knife holder, Gripping aids, Neera container and knife

Fig. 4 Palmyrah tree climbing device with safety feratures

Upper and lower frame assembly fitted in palmyrah tree

Alternate sitting and standing action of worker for ascending/descending

Ladder used for fitting the device at 3 m height form ground level

Tapping neera and Harvesting of fruit bunches

body part discomfort score (BPDS). The Corlett and Bishop (1976) technique of 10: point psychophysical rating scale (0: No discomfort, 10: Extreme discomfort) for the assessment of (ODR and the localized discomfort for BPDS. For the assessment of safety rating, a 10: point psychophysical rating scale (0: Completely secure and no fear, 10: Totally insecure and extreme fear) and for the assessment of ease of operation, a 10: point psychophysical rating scale (0: Very easy, 10: Extremely difficult) was used which are an adoption of Corlett and Bishop (1976) technique.

Results and Discussion

Performance Evaluation

The results of performance evaluation of palmyrah tree climbing device with safety features and conventional method for harvesting fruit bunches and tapping neera are furnished in **Table 2**.

The capacity of palmyrah tree climbing device with safety features for harvesting fruit bunches and tapping neera was lower than the conventional method. The may be due to the proficiency level of the skilled workers in traditional method. However the use of ergo refined palmyrah tree climbing device by unskilled labour with enhanced safety, comfort and stability will alleviate the acute skilled labour constraints in palmyrah cultivation. The cost of fruit bunch harvesting and neera tapping operation using palmyrah tree climbing device with safety features was almost same as that of conventional method. Both the operations of harvesting fruit bunches and tapping neera are performed by a handful of skilled workers only on contract basis, the cost of operation is comparable. The cost of the ergo refined palmyrah tree climbing device with the ladder is Rs. 7,000.

Ergonomic Benefits

To ascertain the improved comfort, safety and ease of operation of the palmyrah tree climbing device for harvesting fruit bunches and tapping neera, the ergonomic parameters are measured compared with conventional method and the

Table 1 Specifications of Palmyrah tree climbing device with safety features

Particulars	Values
Over all dimensions of upper frame (L × B × H), mm	1,125 × 545 × 730
Size of the lower frame (L × B), mm	600 × 515
Size of the rigid base section in upper frame (L × B), mm	575 × 514
Size of tree gripping section in upper frame (L × B), mm	465 × 525
Number of cross rail in upper frame	3
Number of cross rail in lower frame	4
Length of gripping aid (rubber bush) in "U " shaped adjustable frame, mm	215
Length of gripping aid (rubber bush) in cross rail of tree gripping section, mm	100
Diameter of rubber gripping bush, mm	50
Gripping diameter of tree trunk in extendable 'U" frame, mm	200-400 mm adjustable in 5 steps
Mechanism for adjusting the gripping diameter while ascending or descending the tree	Turnbuckle mechanism
Number of gripping aids (rubber bush) in upper frame	3
Number of gripping aid (rubber bush) in lower frame	3
Total weight of the climbing device, kg	16.7
Weight of the lower frame, kg	5.5
Weight of the upper frame, kg	11.2
Seating arrangement	Rigid type (adjustable and pivotable)
Diameter of lime container holding ring, mm	80
Diameter of wooden tongs holding ring, mm	60
Length of wooden tongs, mm	920
Weight of wooden tongs, kg	1.2
Height of ladder, mm	3,000
Weight of ladder, kg	14.9
Size of platform on ladder top (L × B × H), mm	385 × 300 × 20

Table 2 Results of field performance evaluation of palmyrah tree climbing

DETAILS	Palmyrah tree climbing practices	
	Conventional method	Palmyrah tree climbing device
Total time consumed (for ascending, performing operations and descending) per tree, s	240	514
Number of trees climbed per hour	15	7
Number of fruit bunches harvested per hour	80	20
Quantity of fruit bunches harvested per hour	720	180
Quantity of neera collected, lit per hour	120	78
Cost of ascending, fruit bunches harvesting and descending palmyrah tree, Rs. per tree (Operation performed only on contract basis only)	15.00	-
Cost of operation of palmyrah tree climbing device, Rs. per hour	-	52.70
Cost of fruit bunch harvesting, Rs per kg	0.32	0.29
Cost of ascending, tapping neera and descending palmyrah tree, Rs. per tree (Operation performed only on contract basis only)	5.00	-
Cost of tapping neera, Rs./lit	0.63	0.68

Table 3 Comparison of ergonomic parameters of palmyrah tree climbing practices

Parameters	Conventional method	Palmyrah tree climbing practice
A. Neera tapping		
Heart rate, beats min^{-1}	160	130
Energy expenditure, kJ min^{-1}	34.4	24.9
ODR	8.0	4.6
Over all safety rating (OSR)	2.0	8.2
Ease of operation rating (OER)	2.7	7.9
Body Part discomfort score (BPDS)	51	32
B. Fruit bunch harvesting		
Heart rate, beats min^{-1}	168	136
Energy expenditure, kJ min^{-1}	36.8	26.2
ODR	8.3	5.1
Over all safety rating (OSR)	1.9	8.9
Ease of operation rating (OER)	2.5	8.2
Body Part discomfort score (BPDS)	55	35

values are furnished in **Table 3**.

The use of palmyrah tree climbing device enhanced the comfort of the workers with 28, 43 and 37 percent reduction in energy expenditure, overall discomfort rating (ODR) and body part discomfort score (BPDS) respectively. The safety and ease of neera tapping operation was increased by four and three times respectively when compared with conventional method.

The use of palmyrah tree climbing device enhanced the comfort of the subjects with 29, 36 and 36 percent reduction in energy expenditure, overall discomfort rating (ODR) and body part discomfort score (BPDS) respectively. The safety and ease of neera tapping operation was increased by four and three times respectively when compared with conventional method.

Conclusions

For enhanced safety and comfort of the user, a palmyrah tree climbing device with safety features viz., adjustable and pivotable seating arrangement, improved configuration of tree holding section, side support in any direction, safety rope and turn buckle mechanism has been developed out. The performance of palmyrah tree climbing device was evaluated in terms of safety, comfort, output, saving in cost and time of operation and compared with conventional method. The use of palmyrah tree climbing device enhanced the comfort of the subjects with 28-29, 36-43 and 36-37 percent reduction in energy expenditure, overall discomfort rating (ODR) and body part discomfort score (BPDS) respectively and increased the safety and ease of operation by four and three folds respectively for neera tapping and fruit harvesting operations when compared with conventional method. Though the capacity of palmyrah tree climbing device with safety features for harvesting fruit bunches and tapping neera was lower than the conventional method, It resulted in alleviation of acute skilled labour constraints in palmyrah cultivation. The cost of fruit bunch harvesting and neera tapping operation using palmyrah tree climbing device with safety features is comaparable. The cost of the ergo refined palmyrah tree climbing device with the ladder is Rs.7,000.

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■■

Effect of Blade Width and Spading Frequency of Spading Machine on Specific Soil Resistance and Pulverisation




by

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Abstract

The effect of blade width and spading frequency on various dependent variables, i.e. specific soil resistance, energy consumed per unit volume of soil moved, weighted mean clod size, soil bulk density, cone index and cone index ratio were studied. The experiments were conducted in a soil bin on soil having 15.7 % clay, 53.6 % silt, and 30.7 % sand. During experimentation, moisture content of soil was maintained between 13 and 14 %. Blade widths used were straight, 10 cm (W_1) and 15 cm (W_2) and spading frequencies F_1 (1.85 Hz), F_2 (2.31 Hz), F_3 (3.08 Hz) and F_4 (4.62 Hz). The values of dependent variables increased with increase in blade width and decreased with increase in spading frequency. However, the cone index ratio decreased with increase in blade width and increased with increase in spading frequency. Hence, for maximum soil pulverization and optimal specific soil resistance and energy consumption, smaller blade width and higher spading frequency were found to be better.

Keywords: Spading machine, Blade width, Spading frequency

Introduction

Tillage is a major farming operation for seedbed preparation. Tillage tools direct energy into the soil to produce desired effects such as cutting, breaking, inversion and movement of soil. Soil is thus, transformed from an initial condition to a desired final condition by this process (Ros *et al*., 1995). Thus, increasing effectiveness of a tillage tool, even by a small fraction, amounts to considerable saving in energy. Energy required to force a tillage tool through the soil is used to overcome the mechanical strength of the soil and to cause displacement, which results in compaction or break-up (Gill, 1969). Therefore, it is, rather imperative and more economical to improve the productivity of each machine for useful function or reducing the frequency of operation rather than employing more number of machines indiscriminately. Rotary tillers are popular machines for a single pass tillage operation. But, the rotary tillers consume more energy than conventional tillage implement. However, degree of pulverization or tillage efficiency varies considerably in terms of seed germination with these tillage tools. Each point on the blades of a rotary tiller travels through a trochoidal path in the soil. On the forward part of the trochoidal path, the blade would cut or fracture untilled soil and on the backside of the trochoidal, the blade would tend to mix and pulverize the soil slices, (Kinzel *et al*., 1981). The energy requirement increases when the back surface of the blade interacts with the uncut soil and causes undue compaction of the uncut soil. Spading machines could be an alternative. Spading machine is a PTO powered implement designed to approximate the effect of proven

smaller-scale hand digging tool for the purpose of deeper aeration, and effective integration of organic matter. It has been claimed that their action subtly aerated/fractured the subsoil twice the depth of the stroke of the spades (Manfred Palmer, 2002). The claimed advantage of this machine is that it does not form any hardpan as the path of the tools in the soil never runs parallel to the soil surface. An attempt was made to develop a spading machine having non-interactive tool path of blade back surface with uncut soil (Sambhi 2006). The machine was evaluated with straight flat blades whereas the manual spades consisted of a long stick and a small blade with different shapes and angle that had been used for tillage purpose through ages. The blade width is an important factor, as it influences the volume of soil manipulated. Hence, the aim of this study was to investigate the effect of blade width and spading frequency on performance of spading machine.

Materials and Methods

Location

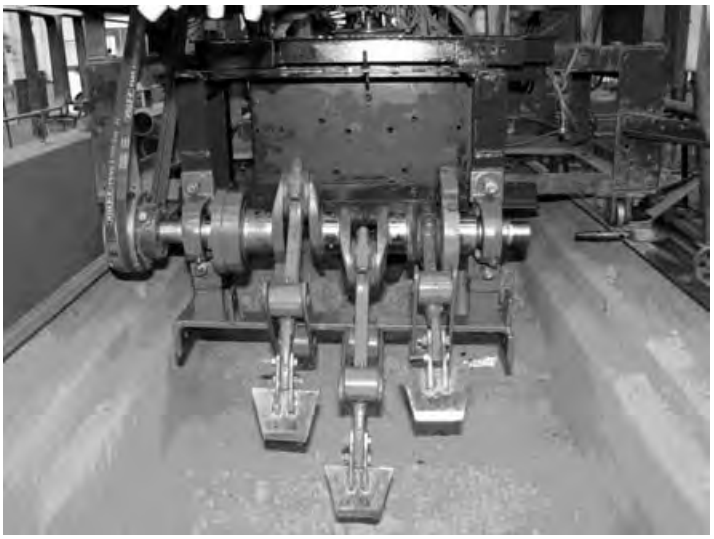
The study was conducted between May, 2006 and Aug, 2007 in the Department of Farm Machinery & Power Engineering, Punjab Agricultural University Ludhiana Punjab, India.

Experimental Method

The laboratory models (**Fig. 1**) of the spading machine with blade widths of 10 cm (W_1) and 15 cm (W_2) were evaluated in field soil in the soil bin. Four levels of bite lengths 4, 6, 8 & 10 cm at travel speed of 18.47 cm/s were selected for the study. These correspond to four levels of spading frequencies F_1 (1.85 cycles/s), F_2 (2.31Hz), F_3 (3.08 Hz) and F_4 (4.62 Hz. Spading frequency was determined by dividing the travel speed by bite length.

The effect on various dependent variables, i.e. specific soil resistance encountered, energy consumed per

Fig. 1 View of experimental spading machine mouinted on tool carriage in a soil-bin



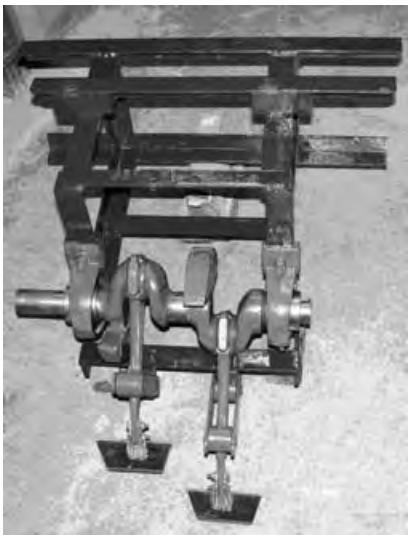


Fig. 2 View of compressor, pneumatic cylinders and controls used for tool carriage in soil bin

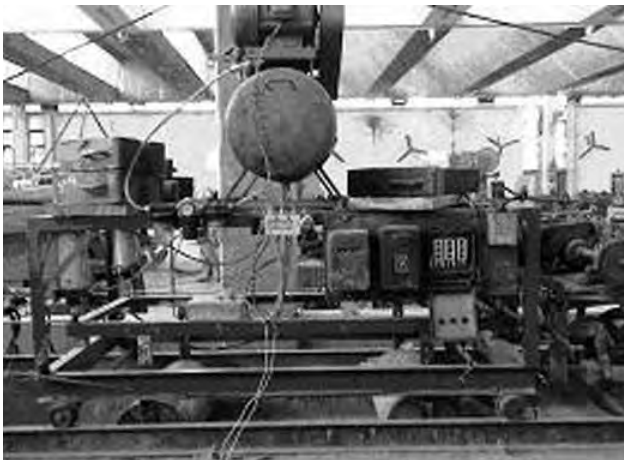
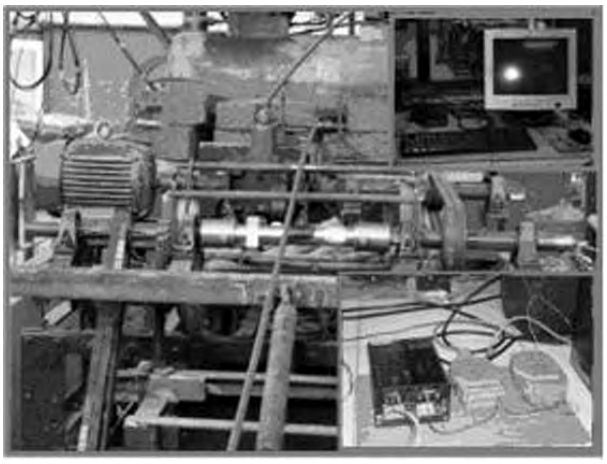


Fig. 3 Torque transducer pasted of shaft



unit volume, weighted mean clod size, soil bulk density, soil cone index and cone index ratio had been studied. The field soil was brought from Gurdaspur, Punjab, India, and filled in the soil bin. The soil was then pulverized by a roto-tiller and compacted by pneumatically pressurised rollers at a constant upward pressure of 0.1 MPa in first run followed by constant downward pressure of 0.1 MPa in second run (**Fig. 2**). Core samples were drawn for moisture content (at regular interval), bulk density (before & after test) and soil strength determination (before & after test) from random points. After each test, clod size distribution samples were removed and processed for the distribution of aggregates determined by placing a sample in the nested group of thirteen sieves ranging in sizes from 0.075 to 100 mm and sieving for two minute.

A wireless strain gauge type torque transducer mounted on intermediate shaft of tool carriage trolley had been used to measure shaft torque. The torque sensor (strain gauge) was pasted on the intermediate shaft rotating spading machine. A 9-volt battery, a transmitter and an antenna were strapped on the same shaft (**Fig. 3**). Another magnetic mount receiving antenna was positioned near transmitter within six meters. Before starting each test the receiver unit and the software was set 'ON'. Then the laboratory model of spading machine was run in the soil-bin. The data in tabular form along with the graphical representation was available on monitor of computer and was recorded. The generated table was exported to a spreadsheet and saved as an excel file.

Specific soil resistance encountered was determined by dividing average shaft torque by arm length of spading mechanism and frontal area of blade. Energy consumed per unit volume of soil moved was determined by dividing power to volume of soil moved per bite. Cone index ratio was determined by dividing initial cone index by final cone index. The hypothesis selected for optimization was that the soil pulverization should be the maximum. Specific soil resistance and energy consumption should be optimal.

The observations recorded on specific soil resistance encountered, energy consumed per unit volume of soil moved, weighted mean clod size, soil bulk density, soil cone index and cone index ratio were analysed using analysis of variance and conclusions were drawn by testing the significance of difference between various levels /combinations of factor levels. All the differences were tested at 5 % level of significance.

Results and Discussion

The experiments were conducted on soil comprising 15.7 % clay, 53.6 % silt and 30.7 % sand. During experimentation, moisture content of soil was maintained between 13 and 14 %. The effect of blade width and spading frequency on various dependent variables, i.e. specific soil resistance encountered, energy consumed per unit volume of soil moved, weighted mean clod size, soil bulk density and soil cone index were directly related. The increase in blade width caused increase in various dependent variables.

Fig. 4 Effect of different blade widths on specific soil resistance

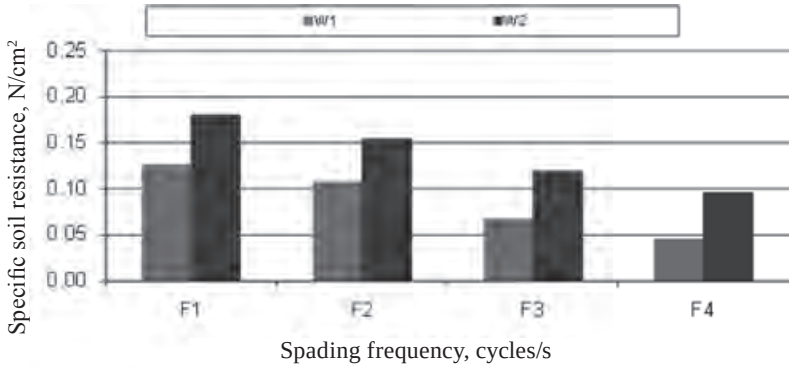
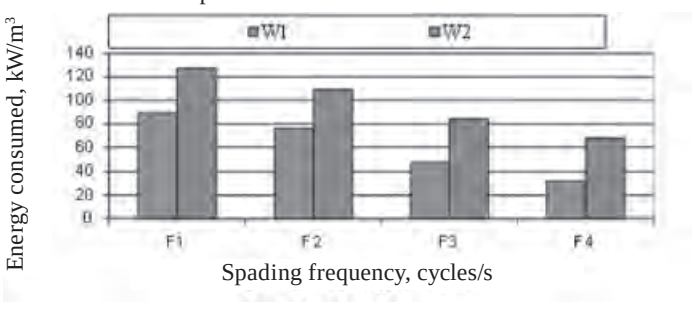


Fig. 5 Effect of different blade widths on energy consumed per unit volume of soil moved



Effect of Blade Width on Specific Soil Resistance

The difference between two blade widths was significantly different. Differences in spading frequency were also significant. All the differences were tested at 5 % level of significance. However, no interaction between blade width and spading frequency was observed in specific soil resistance encountered. It was evident from **Fig. 4** that specific soil resistance encountered increased with increase in blade width. However, it decreased with increase in

spading frequency. Specific soil resistance encountered was lower for W_1 (10 cm) compared to W_2 (15 cm), because with smaller blade fracture planes developed in smaller area as compared to bigger blade. Specific soil resistance encountered for both types of blades varied between 0.05 N/cm^2 and 0.18 N/cm^2 for different spading frequencies.

Effect of Blade width on Energy Consumed per Unit Volume of Soil Moved

Energy consumed per unit volume of soil moved was significantly different for both blade widths. Differences in spading frequency were also significant. However, no interaction between blade width and spading frequency was observed in energy consumed per unit volume of soil moved. All the differences were tested at 5 % level of significance. Energy consumed was lesser for smaller blade as compared to larger blade. It was due to the fact that with smaller blade more fracture planes were developed in smaller area as compared to larger blade. Energy consumed per unit volume of soil moved also decreased with increase in spading frequency. The information has been plotted in **Fig. 5**. The minimum energy consumption per unit volume of soil moved was 32.09 kW^{-s}/m^3 & maximum energy consumed per unit of volume of soil moved was 127.27 kW^{-s}/m^3 at different spading frequencies.

Effect of Blade width on Weighted Mean Clod Size

The mean clod size increased with increase in blade width, but it decreased with increase in spading frequency. The differences between two blade widths were significantly different. The interaction between blade width and spading frequency was also significant. Differences between two blade widths were maximum for spading frequency F_1 and minimum for F_4. The information has been plotted in **Fig. 6**. The minimum mean clod size for W_1 was 2.22 mm & maximum mean clod size for blade width W_2 was 12.15 mm. Larger blade width resulted in large failure planes thus larger chunk of soil mass was removed. Hence, bigger clods were formed with large blade width. This resulted in lesser pulverisation and bigger clods as compared to that of smaller blade. However, at higher spading frequency the effect of blade width diminishes. This may be due to smaller chunk of soil lifted at higher bite frequency.

Effect of Blade width on Bulk Density

The differences between the two blade widths were significantly different. Differences in spading frequency were also significant. However, no interaction between blade width and spading frequency was observed in soil bulk density. Soil bulk density was more with W_2 (15 cm) as compared to W_1 (10 cm) as bigger clods were formed with wider blade. Bulk density for two types of blades varied between 1.26 Mg/m^3 to 1.36 Mg/m^3 for different spading frequency. Information plotted in **Fig. 7** indicated that achieved bulk density was always higher with W_2 i.e. 15 cm blade width. It was also evident that with increase in spading frequency the achieved bulk density decreased. The soil mass with bigger clods have higher bulk density because inter-granular air space is not proportionate to clod size. The bigger clods resulted in higher percentage of soil per unit volume as compared with that of smaller clods, so soil bulk density was higher with bigger blade width.

Effect of Blade width on Cone Index

The differences between two blade widths on Cone index were significantly different. Differences in spading frequency were also significant. However, no interaction between blade width and spading frequency was observed in Cone

Fig. 6 Effect of different blade widths on mean clod size

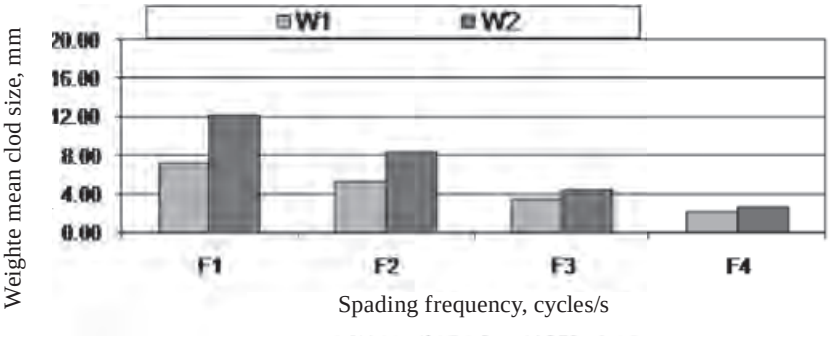
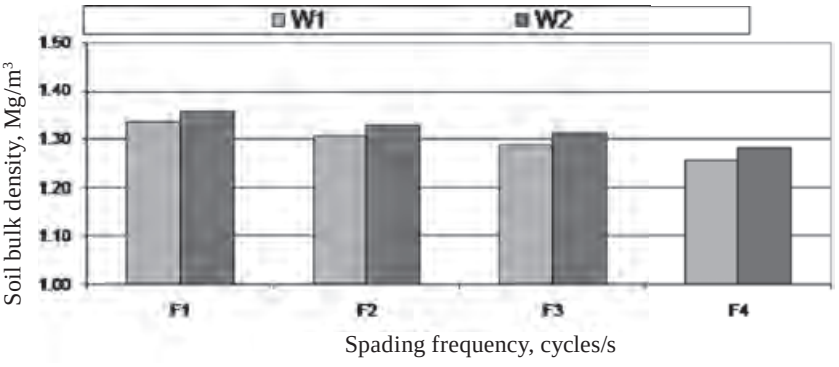


Fig. 7 Effect of different blade widths on soil bulk density



index. Cone index was lesser with W_1 (10 cm) blade width as compared to W_2 (15 cm) blade width as bigger clods were formed with bigger blade width. Cone index of two types of blades varied between 0.43 MPa to 0.51 MPa for different spading frequency. The results of effect of blade width have been plotted in **Fig. 8**. The Cone index decreased with increase in spading frequency. Mean clod weight diameter was more for bigger blades. Since, inter-granular space was not proportionate to the clod size and bulk density was more and hence Cone index was more with bigger blades.

Effect of Blade width on Cone Index Ratio

The differences between two blade widths on Cone index ratio were significantly different. Differences in spading frequency were also significant. However, no interaction between blade width and spading frequency was observed in cone index ratio. Cone index ratio was more with blade width W_1 (10 cm) as compared to W_2 (15 cm) as bigger clods were formed with bigger blade width. It was revealed from **Fig. 9** that cone index ratio of two types of blades varied from 1.63 to 1.91 for different spading frequency. However, Cone index ratio increased with increase in spading frequency. Mean clod weight diameter was more for bigger blades. Since, inter-granular space was not proportionate to the clod size bulk density was more and hence cone index was more with bigger blades. Therefore, Cone index ratio was lesser with bigger blades.

Two criteria for optimization were used. These were the pulverization should be the maximum and the energy consumption and soil resistance should be optimal. For maximum pulverization, weighted mean clod size, soil bulk density and soil cone index should be the minimum. Weighted mean clod size decreased with increase in spading frequency. Weighted mean clod size was the minimum for spading frequency F_4. The weighted mean clod size was the minimum for smaller blades i.e. W_1. Therefore, combination W_1F_4 was superior.

Soil bulk density decreased with increase in spading frequency. Soil bulk density was the minimum for F_4. The soil bulk density was also the minimum for smaller blades. Hence, minimum value of soil bulk density was observed at combination W_1F_4.

Cone index was the minimum with spading frequency F_4 as compared with other spading frequencies. Therefore, F_4 was considered to be better than spading frequencies F_1, F_2 & F_3. Soil cone index was lesser for W_1 as compared with W_2. Therefore, W_1 was considered better than W_2. Therefore, combination W_1F_4 was considered the best.

Energy consumed should be optimal. Energy consumed per unit volume for blade width W_1 was lesser and it increased with increase in blade width. Higher energy consumption with bigger blades was caused due to bigger fracture planes. Probable the cracks went much deeper requiring higher energy. Although deeper cracks were preferable but energy consumption was almost 40 % more. Therefore, smaller blades W_1 appeared to be superior to W_2. Further, energy consumed per unit volume of soil moved decreased with increase in spading frequency. The reason for this could be that volume of soil deformed was mini-

Fig. 8 Effect of different blade widths on Cone index

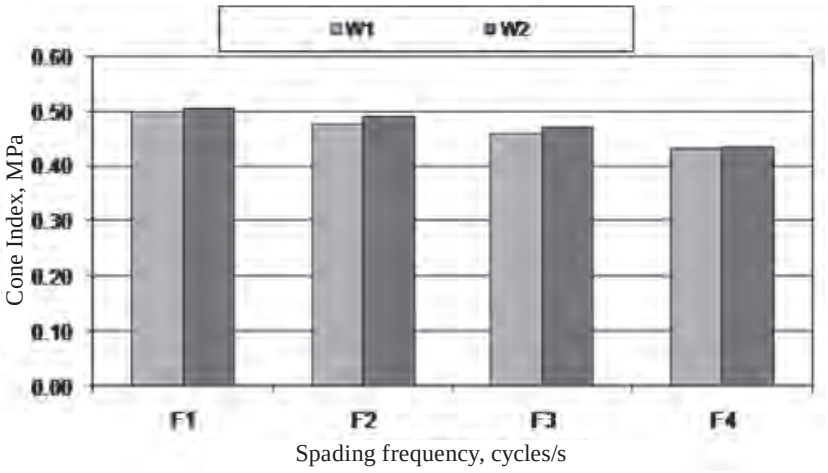


Fig. 9 Effect of different blade widths on Cone index ratio

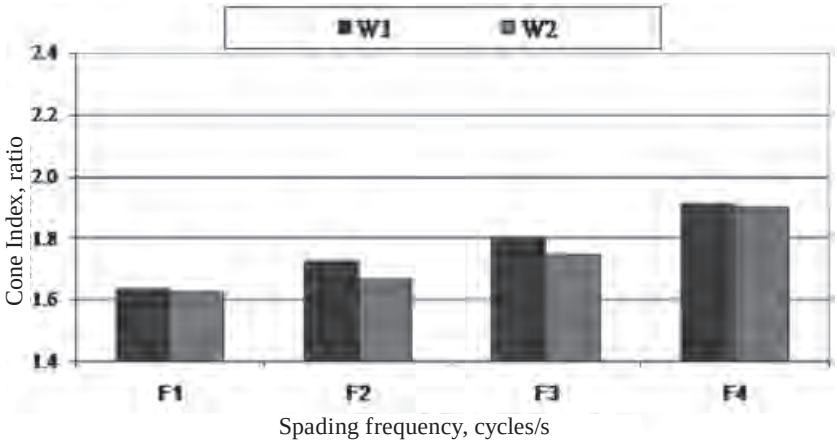


Table 1 Optimum Values of Independent Parameters

Parameters	Values
Blade Width (W), cm	10
Spading Frequency (F), Hz	4.62

mum for higher spading frequency. As the sphere of influence increased with lower spading frequency, the energy consumption increased. This increase surpassed the reduction in energy consumption due to lesser soil-metal friction at smaller cutting widths. The energy consumed per unit soil moved was least for spading frequency F_4 as compared to F_1, F_2 & F_3 respectively. Therefore, higher spading frequency F_4 was superior. Therefore, best combination from energy consumption per unit soil moved point of view was W_1F_4.

Specific soil resistance encountered should be optimal. Specific soil resistance encountered was lower for W_1 as compared to W_2 because the failure planes were wide apart in case of bigger blade causing lesser internal fragmentation produced resulting in higher soil resistance. Specific soil resistance encountered decreased with increase in spading frequency. Since the specific soil resistance encountered was least for spading frequency F_4 as compared to F_1, F_2 & F_3 so spading frequency F_4 was considered optimal than F_1, F_2 & F_3. Therefore, best combination from specific soil resistance encountered point of view was W_1F_4. Therefore, the best combination for pulverization maximum, energy consumed and soil resistance encountered optimal was W_1F_4.

Conclusions

1. Specific soil resistance encountered during spading decreased with increase spading frequency. However, it increased with increase in blade width. Specific soil resistance encountered while spading varied from 0.05 N/cm^2 to 0.18 N/cm^2 at different blade widths. Minimum specific soil resistance was encountered for 10 cm wide blade and 4.62 Hz spading frequency. Whereas maximum specific soil resistance was encountered for 15 cm wide blade and 1.85 Hz spading frequency.
2. Energy consumed decreased with increase in spading frequency. However, it increased with increase in blade width. Energy consumed per unit volume of soil moved varied from 32.09 to 127.27 kW^{-s}/m^3 at different blade widths. Minimum energy consumed was observed for 10cm wide blade and 4.62 Hz spading frequency. Maximum energy consumed was observed for 15cm wide blade and 1.85 Hz spading frequency. Weighted mean clod size decreased with increase in spading frequency. However, it increased with increase in blade width.
3. Weighted mean clod size varied between 2.22 to 12.15 mm at different blade widths. Minimum weighted mean clod size was observed for 10 cm wide blade and 4.62 Hz spading frequency. Maximum weighted mean clod size was observed for blade 15cm wide and 1.85 Hz spading frequency.
4. Soil bulk density decreased with increase in spading frequency. However, it increased with increase in blade width. Soil bulk density varied between 1.26 to 1.36 Mg/m^3 at different blade widths. Minimum soil bulk density was observed for 10cm wide blade and 4.62 Hz spading frequency. Maximum soil bulk density was observed for blade 15 cm wide and 1.85 Hz spading frequency.
5. Cone index decreased with increase in spading frequency. However, it increased with increase in blade width. Cone index varied between 0.43 MPa to 0.51 MPa at different blade widths. Minimum cone index was observed for blade 10 cm wide and 4.62 Hz spading frequency. Maximum Cone index was observed for blade 15 cm wide and 1.85 Hz spading frequency.
6. Cone index ratio increased with increase in spading frequency. However, it decreased with increase in blade width. Cone index ratio varied from 1.63 to 1.91. Minimum cone index ratio was observed for 15 cm wide blade and 1.85 Hz spading frequency. Maximum cone index ratio was observed for 10 cm wide blade and 4.62 Hz spading frequency.
7. Maximum pulverization and optimal energy consumption/ soil resistance encountered the best combination was W_1F_4.

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Agricultural Mechanization Situation in the Palestinian Territories

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Abstract

In this paper, general information about agricultural and agricultural mechanization situation in Palestinian territories is presented taking into consideration that there is a scarce in articles related to agricultural mechanization in Palestinian territories. Different activities of Ministry of Agriculture (MOA) in the Palestinian National Authority (PNA) related to agricultural mechanization are discussed. Situation of several machineries (e.g. tractors, tillage equipments, sprayers, grain drills and seeders, threshing machines, potato planters and harvesting machine) and future vision are presented. Generally, there is no balance between the number of agricultural machines and the total planted area, and there is a need for more advanced efficient agricultural machines.

Introduction

Agriculture plays a crucial role of the Palestinian national, social, cultural and economic structure. The Palestinian agricultural area in 2010 was approximately 95,717 ha, which is about 30 % of the total area of Palestinian territories land (6,210 km^2), including 92.1 % in the West Bank and 7.9 % in the Gaza Strip (**Fig. 1**). The agricultural sector contributed 8.1 % of the gross domestic product (GDP) in 2007. Significant quantities of vegetables, olive oil and flowers are mainly exported to Israel, European Union (EU) members' states and some Arab countries (Palestinian National Authority, 2009).

The total population of the Palestinian territories in 2010 was about 4.152 million (World Bank, 2012). There are about 292 thousands employees in agricultural holdings in the Palestinian territories, and around 12 % of men and 30 % of women of the total employment (Japan International Cooperation Agency, 2007).

Ministry of Agriculture (MOA) in the Palestinian National Authority (PNA) was established in 1994, and it leads the agricultural policy in the Palestinian territories.

According to the Palestinian Central Bureau of Statistics (2011) there are about 71 % of agricultural holdings are plant holdings, about 29 % of agricultural holders aged 40-49 years, about 79 % of agricultural holdings cultivated with permanent and temporary crops, about 33 % of the area cultivated with field crops was in Hebron governorate, about 21 % of the area cultivated with vegetables was in Jericho and Al-Aghwar governorate, about 19 % of the area cultivated with tree horticulture was in Jenin governorate, Hebron had greatest number of cattle, Jerusalem the least, and olive trees represent about 67 % of the total number of horticultural trees.

The rain-fed area constitutes 86 % of the cultivated land, including

Fig. 1 The Palestinian territories

Source: European commission, 2012

97 % in the West Bank and 3 % in Gaza. The irrigated area consists of 14 % of the total arable land, including 56 % in the West Bank and 44 % in the Gaza Strip (Palestinian National Authority, 2009).

The annual average precipitation in West Bank and Gaza in 2009 was 402 mm per year (World Bank, 2012). The Palestinian territories has a multiple agricultural environments and diversity of climate that is suitable to produce several crops over different periods of the year (Palestinian National Authority, 2009).

The crop production index (1999-2001 = 100) in West Bank and Gaza was 104 in 2009. Crop production index shows agricultural production for each year relative to the base period 1999-2001. It includes all crops except fodder crops. Regional and income group aggregates for the Food and Agricultural Organization's (FAO) production indexes are calculated from the underlying values in international dollars, normalized to the base period 1999-2001 (World Bank, 2012).

There is a scarce of articles and reports about agricultural mechanization in Palestinian territories. This contribution documents the current situation of agricultural mechanization. This will help for any future projects and development related to agriculture and agricultural mechanization in this area.

Table 1 Number of agricultural machines in the Palestinian territories by type and governorate in 2007/2008

Types of machines and equipment	Palestinian territories	West Bank	Gaza strip
Four-wheel tractor	7,734	7,001	733
Track-laying tractor	22	17	5
Trailer	5,188	4,889	299
Water tank	3,139	3,017	122
Cultivator	5,012	4,748	264
Plough	3,714	3,409	305
Mold broad plough	138	65	73
Disk	314	289	25
Disk harrows	122	94	28
Spike -tooth harrow	350	331	19
Leveling box	333	305	28
Plastic spreader	434	421	13
Ridger	276	247	29
Broad caster	192	178	14
Furrow fertilizer	186	182	4
Manure spreader	60	51	9
Rotary tiller	614	350	264
Turbine	157	146	11
Grain drill	119	106	13
Seeder	54	49	5
Potatoes planter	18	5	13
Potatoes digger	27	13	14
Sprayer	1,529	1,177	352
Cutter - bar	28	17	11
Cutter - disk	26	18	8
Finger wheel rakes	74	63	11
Baler	231	133	98
Thresher	484	482	2
Miller	45	45	0
Grounder	54	54	0
Reaper-binder	68	52	16
Combine	62	39	23
Total	30,804	27,993	2,811

(Source: Palestinian Central Bureau of Statistics, 2009)

Agricultural Machinery in Palestinian Territories

The number of agricultural machines and equipments in the Palestinian territories by type and governorate in 2007/2008 is shown in **Table 1**.

Some points related to agricultural mechanization will be discussed below.

Tractors

There are more than 7,700 tractors in Palestinian territories, having power range between 34-45 horsepower (hp). The agricultural tractors per 100 sq. km of arable land in West Bank and Gaza was reported at 767.92 in 2008 (World Bank, 2012). Tractor horsepower rate is 0.6 hp/ha, and MOA has a goal to raise it in the future to 2.5 hp/ha by increasing the number of efficient tractors, since there is no balance between the number of tractors and the total planted area. Recently there are some companies entering Palestinian's market with reasonable prices for new tractors.

Recent tractor models are mostly: Fiat, Ford, New Holland, John Deere and David Brawn. About 70 % of the total number of tractors are more than 20 years old. Eighty percent of tractors are used for agricultural purposes and 20 % are used for industry purposes. Around 30 % percent of the agricultural tractors are legal, and the rest are illegal. These illegal tractors are considered dangerous for driving on the roads, cause pollution to the environment and has no safety life equipments like roll over protection structure (ROPS).

Tillage Systems and Equipment

Most of the tillage equipments are conventional (traditional) equipments. The farmers usually use the deep tillage in irrigated areas, and some arid and semi arid zones. The deep tillage leads to soil erosion, which leads to lose of water and soil moisture, and this decreases the agricultural production.

In areas having a high rain-fall there is soil erosion problem, especially in the high lands on the mountains. Extension activities in the Palestinian MOA try to solve this problem by introducing minimum tillage concept, building terraces and demonstration activities in agricultural research stations.

Sprayers

Most of sprayers are old. The capacity of sprayers are between 500-1,000 liters. The nozzles booms and guns are used to spray the crops. Mist sprayer machines are not available.

Grain Drills and Seeders

The grain seeding in twenty percent of the area is manually spreading the grain by hands, and 80 % use grain drills and seeders. The grain drills and seeders are concentrated in the northern part of Palestinian territories (coastal and semi coastal areas, and high rain fall region). The grain drills are used for wheat, barley, chickpeas, clover and other field crops. Seeders are used for parsley, carrots, onion and garlic crops that are rare, and only few of them are in use. Moreover, 95 % of the grain drills are more than 20 years old.

Threshing Machine

There is just one type of threshing machine, which is locally made and operated from tractor (35 hp or over) by universal joint. It is used for wheat, barley and chickpeas. It separates the grain from the straw which is used for feeding animals.

Potato Planters

The potato cultivation covers 1,695 ha. About 25 % of the area is planted by potato planter machines and the rest is planted by potato diggers with help of conventional plough.

Harvesting Machines

The numbers of harvesting machines (combines and reaper-binders) are not enough for harvesting the total planted area (i.e. there is no balance between the number of harvesting machines and total planted area). The lacking of machines forces the farmers to rent the machines from machines' owners, and this can affect the price of the harvested crops. Moreover, there are many difficulties in harvesting process due to separated and limited areas of cultivated lands, high cost of maintenance and most of the combines are concentrated in the northern part of Palestinian territories. There is also a problem in harvesting wheat in high and narrow areas. For lentils, there is a harvesting problem related to local varieties that are not standing vertically (i.e. inclined).

For forage, the mowers and rotary cutter are rare too. Balers are old styles, with low efficiency. MOA is working to find suitable alternatives for harvesting and collecting forage machines, by using an experimental combine with 150-200 cm operating width and maneuvering on the narrow and high lands.

Activities of MOA

The agricultural policies in the Palestinian territories are directed by MOA in the PNA. Agricultural mechanization department in MOA is trying to improve the level of agricultural mechanization in Palestinian territories through:

- Free extension services,
- Transfer of the knowledge to the farmers though brochures (Meshmesh and Abu-Khalaf, 1998, Natour and Salawdeh, 2011), trials and field days at experimental stations that are located in different areas,
- Renting some of its machines to the farmers and cooperatives for long periods and for free,
- Trying to help farmers through introducing new machines and technologies (The land of my country website, 2011), and
- Working in close collaboration with research centers at local universities.

Agricultural Challenges in the Palestinian Territories

There are several agricultural challenges in Palestinian territories that affect the agricultural mechanization sector. These challenges include:

- The economical problem: high prices of agricultural input, seeds, fertilizers, water, machines and other materials,
- Weakness of some agricultural cooperatives,
- Level of technology is relatively low, and does not face the future challenges, and
- There is a decrease of the agricultural area, due to the Israeli settlements and the separated wall (Palestinian Central Bureau of Statistics, 2011), deserting and low level rain-fall and ground water storage.

Conclusions

- There is a potential for mechanization in agricultural sector in Palestinian territories, since the agricultural crop productivity index is relatively high, and hopefully it will continue its increase,
- Many of the agricultural machineries are still utilized, despite of the deformation that occurred in its structure and the erosion of its resources. This can be considered as a comparative advantage under the current agricultural situation,
- There is no balance between the number of agricultural machines

and the planted area,

- There is a need to give more attention from different parts to the agricultural mechanization sector due to its important contribution in the agricultural activities and to be able to face the future challenges, and
- Agricultural mechanization needs some time to be able to face the production challenges.

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NEWS

Congratulations!

◆ Dr. Digvir S. Jayas received 2014 Kishida International Award

Dr. Digvir S. Jayas received 2014 Kishida International Award during the 2014 ASABE and CSBE/SCGAB Annual International Meeting. He is currently a vice president (Research and International) and a distinguished professor at University of Manitoba, Winnipeg, Manitoba, Canada, and formerly held a Canada Research Chair in Stored-Grain Ecosystems, conducting research related to drying, handling and storing grains and oilseeds and digital image processing for grading and processing operations in the Agri-Food industry. He has authored or co-authored more than 700 technical articles and 105 invited presentations. He has also collaborated with researchers in various countries, and his research has positively impacted on development of efficient grain storage, handling and drying systems particularly in Canada, China, India, Ukraine and USA. He has received awards from several organizations for his work. Dr. Jayas is very active as the boards of many organizations: he has served as president of Agriculture Institute of Canada, Association of Professional Engineers and Geoscientists of Manitoba, Canadian Institute of Food Science and Technology, Canadian Society for Bioengineering, and Manitoba Institute of Agrologists.

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Performance Evaluation of Motorized Ginger Rhizomes Splitting Machine

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Abstract

A motorized ginger rhizomes splitting machine based on sawing principles with serrated blade was developed in recognition of the constraints imposed by the traditional splitting method. Two ginger varieties (UG I and UG II), 3 feed rates (57, 97, 141 kg/hr), 3 blade shaft speeds (280, 310, 380 rpm) and 3 ginger rhizome sizes (large, medium and small) were used to evaluate the performance of motorized ginger rhizomes splitting machine. A 2 × 33 factorial experiment in a completely randomised block design was used to study the effect and interactions of variables on machine capacity (MC), splitting efficiency (SE), percent injured (PI) and percent dust (PD). Result showed that there was a decrease in SE with increasing speed with UG I having higher values than UG II. Percent damage and percent injured increased with increasing speed with UG II having higher values than UG I. Percent injured and splitting efficiency increased with increasing size of ginger rhizomes with UG I having higher values than UG II. The analysis of variance (ANOVA) showed a highly significant effect of variety and size on the splitting efficiency.

Introduction

Traditional processing of ginger (Zingiber Officinale Roscoe) in Nigeria has been challenged by many problems resulting in low ratings with the associated loss of foreign exchange in the international market. Ginger splitting presently is predominantly done manually mostly by women and children. With unskilled hand, it is estimated that losses of ginger material can be up to 15-20 percent(Akomas and Oti, 1988).

Two commercial varieties of ginger commonly grown in Nigeria are: Umudike Ginger 1, (UG 1) locally called Tafin giwa (monkey finger) has a bold yellow rhizome flesh with stout short internodes. The second is black ginger Umudike Ginger II (UG II) locally called Yatsum Biri (Elephant's foot) because of the very irregular shape of its fingers.

The epidermal cells of ginger contain most of the essential oils which gives ginger its characteristic aroma, a prime factor in determining its market value (Agarwal *et al*., 1987; Ali *et al*., 1991). Ginger splitting is longitudinal to enable maximum surface exposure for quick and uniform drying. Traditional splitting of ginger is done manually which involves holding ginger rhizome with one hand and passing a sharp knife through the rhizome fingers longitudinally cutting it into fairly symmetrical pairs. This operation is tedious, labour intensive, risky and dangerous. It has been reported that this has limited area produced (Onwueme, 1988) as it takes one-man day of 8 hours to split 120 kg of fresh ginger rhizomes (Babawale, 2002).

Efforts are being made to develop ginger splitting machines locally with various degrees of success. A manual ginger slicing machine was developed by Federal Institute of Industrial Research Oshodi (Onu and Okafor, 2002). Throughput of the slicer varied between 22.22 to 28.85 kg/hr. The slicing efficiency varied between 66 ± 0.9 and 72.4 ± 6.4. Simonyan *et al*. (2003) developed a motorised ginger slicer which was able to slice ginger rhizomes longitudinally. A slicing efficiency of 64.6 to 76.8 % and damage of

23.2 to 35.4 % was reported. Guwo *et al*. (2008) developed a splitting machine and evaluated the machine performance at three moisture levels, five impeller speed levels using two ginger varieties (Tafin giwa and Yatsun Biri). Guwo *et al*. (2008) reported that splitting efficiency of the two ginger varieties decreased with increasing impeller speed and decrease in moisture content. Maximum splitting efficiency of the machine was 82.15 % for Tafin giwa and 67.95 % for Yatsum Biri at 240 rpm and 84.35 % wb respectively.

In recognition of the constraints imposed by manual method of splitting ginger which is time consuming and labour intensive , there is need to design and construct a motorised splitting machine that will be entirely fabricated locally. The objective of this study is to report the performance evaluation of a developed ginger rhizomes splitting machine.

Materials and Methods

The study was conducted at the Postharvest Technology Laboratory, Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture, Umudike. Abia State. Nigeria.

Fig. 1 Developed Ginger Rhizomes Splitting Machine

Description of Ginger Rhizomes Splitting Machine

The motorized ginger splitting machine consist of frame, feeding unit, pressing mechanism, splitting mechanism, power transmission and discharging unit. **Fig. 1** shows the developed ginger rhizomes splitting machine.

Frame

The frame constructed with 25 mm by 25 mm angle iron positions all the machine components to perform its operation satisfactorily. It also has 360 mm by 180 mm extension of the stand for the prime mover.

Feeding Unit

The hopper is trapezoidal shaped structure with 141 mm base width, 100 mm top width, 30 mm height and 110 mm wide. The hopper is inclined at 34º to the horizontal to ensure easy movement of ginger rhizomes to the splitting unit under gravity.

Pressing Mechanism: comprises of crank shaft, connecting rod and piston.

Crankshaft: This unit translates the rotary motion of prime mover to reciprocating movement of piston. It has a shaft 25 mm diameter with a ball bearing positioned at centre of the shaft.

Connecting rod: this transmits the rotary motion of crankshaft to reciprocating motion of piston.

Piston: The piston reciprocates vertically within splitting unit housing from top dead centre to bottom dead centre. It opens the inlet space to receive ginger rhizomes from hopper to splitting unit at the bottom dead centre. It closes the inlet space, pushing and guiding ginger rhizomes against the rotating serrated blade for splitting.

Splitting Mechanism

The serrated blade 240 mm diameter is constructed from 2 mm thick stainless steel to prevent corrosion and avoid contamination.

Power Transmission System

A 5 hp Robin petrol engine is the prime movermounted on the stand to help stabilise the machine. Power transmission to the moving parts of splitting machine are by shaft, pulley and belt drive.

Discharging Unit

Discharge unit is an extension of the splitting unit casing. Ginger rhizomes splits are discharged under gravity.

Principle of Operation

The developed splitting machine operates on sawing principle to split the ginger rhizomes. The ginger rhizomes falls freely by gravity through the splitting chamber reorienting the rhizomes longitudinally for splitting. The piston pushes the ginger rhizomes to the rotating serrated blades to be sheared.

Experimental Procedure

The two ginger varieties used were obtained from National Root Crop Research Institute (NRCRI) out-growers in Kachia, Kaduna State, Nigeria. The ginger rhizomes splitting machine was allowed to run for about two minutes to stabilise before feeding cleaned ginger rhizomes through the hopper manually. The feeding time, blade shaft speed and time required for the ginger batch fed into the machine to extrude out was recorded. The feed rate was calculated in kg/h.

The splitted ginger rhizomes, unsplitted ginger rhizomes, injured but splitted rhizomes and ginger dust as a result of splitting with serrated blade were collected and weighed respectively. Also moisture contents of ginger rhizome were determined using procedure detailed by Henderson *et al*. (1997). The moisture contents of ginger rhizomes used during the evaluation were 73.64 % wb and 77.13 % wb for UG I and UG II respectively.

The ginger rhizomes were sorted into large, medium and small sizes. The speed of blade shaft was varied to obtain three speed levels. A Lutron digital photo tachometer was used to measure the blade shaft speed.

Performance Evaluation of Developed Ginger Rhizomes Splitting Machine

The performance of developed ginger rhizomes splitting machine was evaluated as:

$F_R = Q_f / t$ .....(1)

Where F_R is feed rate in kg/h; Q_f is mass of ginger rhizomes fed into the machine in kg and t is time to finish the feeding in hour.

$M_C = Q_f / t$ .....(2)

Where M_C is machine capacity in kg/h; Q_t is mass of ginger rhizome splitted in kg; t time taken for splitting in hour.

$SE = (W_s / W) \times 100$ .....(3)

Where SE is splitting efficiency in percent; W is mass of ginger rhizomes in kg and W_s is mass of ginger rhizomes split in kg.

$PI = (W_i / W) \times 100$ .....(4)

Where PI is percent injured in percentage; W is mass of ginger rhizome in kg and W_i is mass of ginger rhizomes injured in kg.

$PD = (W_s / W) \times 100$ .....(5)

Where PD is percent dust in percentage; Ws is mass of ginger rhizome sawn in form of dust in kg; W is mass of ginger rhizome fed into the machine in kg.

Data Analysis

Two ginger varieties (UG I and UG II), 3 feed rates (57, 97, 141 kg/hr), 3 ginger blade shaft speeds (280, 310, 380 rpm) and 3 ginger sizes (large, medium and small) were used to evaluate the performance of the developed machine.

Table 1 Summary of Analysis of Variance of Effect of Speed on Machine Parameters

Source of variation	Machine Capacity	Splitting Efficiency	Percent Dust
Replicate	1.33	4.09	0.96
Variety	1.78^{NS}	12.99^{**}	11.58^{**}
Feed rate	4.35^{*}	0.29^{NS}	1.49^{NS}
Speed	5.45^{**}	2.66^{NS}	3.48^{*}
Variety vs feed rate	4.22^{*}	0.12^{NS}	2.64^{NS}
Variety vs speed	5.15^{*}	0.12^{NS}	0.04^{NS}
Feed rate vs speed	2.78^{NS}	1.63^{NS}	0.85^{NS}
Variety vs feed rate vs speed	6.66^{**}	1.03^{NS}	0.21^{NS}
Residual	34		
Total	53		

*Significant, **Highly significant, ^{NS} Not significant

A 2×3^3 factorial experiment in a completely randomised block design was used to study the effect and interactions of variables on machine capacity, splitting efficiency, percent injured and percent dust. Replications were made for each treatment level combination. The GenStat 7.2 (DE) (2007) was used to analyse the data.

Results and Discussions

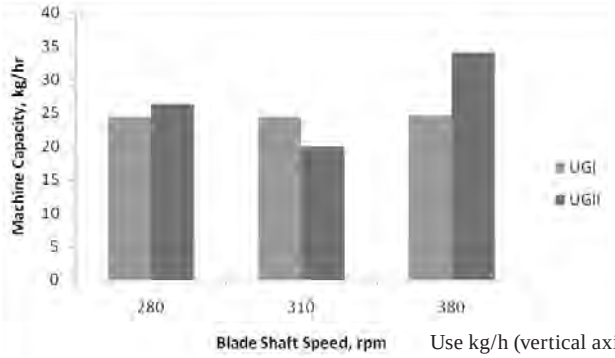
Effect of Speed

There was general increased machine capacity with increasing speed as given in **Fig. 2**. The result is at variance with that of Guwo *et al.* (2010) which reported a decrease in machine capacity with speed. Increasing speed leads to increase inflow of ginger rhizomes through the splitting machine, thereby increasing the machine capacity. Results showed a highly significant effect of speed and interactions of variety, feed rate and speed on machine capacity as shown in **Table 1**. Interaction of variety versus feed rate and variety versus speed on the machine capacity was significant.

The splitting efficiency decreased with increasing speed. Splitting efficiency was higher at 280 rpm than other speeds evaluated for both varieties of ginger as shown in **Fig. 3**. The splitting efficiency of UG I was consistently higher than UG II for all speed tested. This implies that low speed for both varieties of ginger ensures high performance of the splitting machine. This agrees with result of Guwo *et al.* (2010) for UG I variety and Balasubramanian *et al.* (1993) for cassava. There was a highly significant effect of variety on the splitting efficiency of the machine as presented in **Table 1**.

There was an increase in percent dust with increasing speed for UG I and UG II respectively as given in

Fig. 2 Effect of Speed on Machine Capacity



Use kg/h (vertical axis)

Fig. 3 Effect of Speed on Splitting Efficency

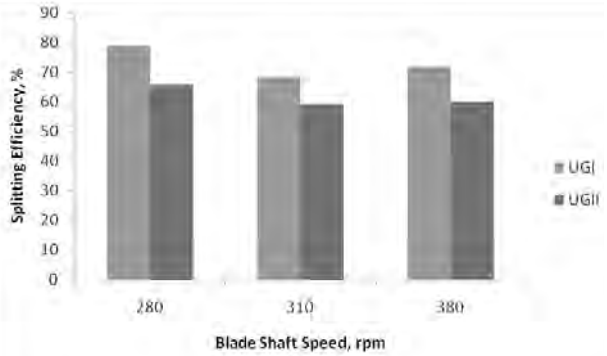


Table 2 Summary of Analysis of Variance of Effect of Ginger Rhizomes Size on Machine Parameters

Source of variation	Machine Capacity	Splitting Efficiency	Percent Injured
Replicate	0.32	0.15^{NS}	0.35^{NS}
Variety	1.17^{NS}	15.15^{**}	0.37^{NS}
Feed rate	5.07^{*}	0.10^{NS}	1.01^{NS}
Size	29.32^{**}	13.62^{**}	6.52^{**}
Variety vs feed rate	1.47^{NS}	2.11^{NS}	0.81^{NS}
Variety vs size	0.50^{NS}	1.65^{NS}	0.99^{NS}
Feed rate vs size	0.60^{NS}	1.11^{NS}	0.67^{NS}
Variety vs feed rate vs size	0.53^{NS}	1.27^{NS}	0.72^{NS}
Residual	34		
Total	53		

*Significant, **Highly significant, ^{NS} Not significant

Fig. 4. The percent dust from UG II was consistently higher than UG I for the speed levels (280 to 380 rpm) evaluated. These results showed that at low speed the machine achieved low dust of ginger for both varieties during splitting operations. There was a highly significant effect of variety and significant effect of speed on percent dust (**Table 1**). The result implies that UG II is more fibrous than UG I. This may be due to UG II fibres being more lignified thereby posing more resistance to cutting.

The percent injured increased with increasing speed for UG I and UG II ginger varieties evaluated is presented in **Fig. 5**. Result indicated that percent injured was low at low speed for both varieties during the splitting operations. The percent injured was higher with UG II than UG I rhizomes.

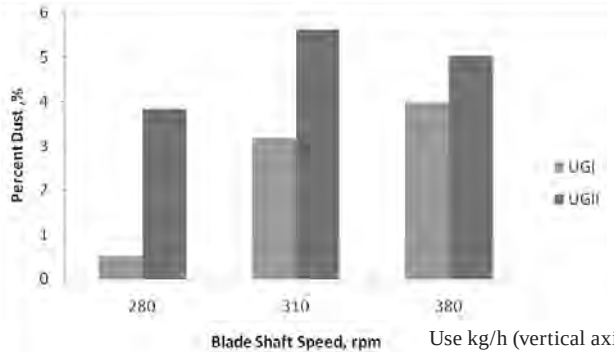
Effect of Ginger Rhizomes Size

There was increasing machine capacity with increase in ginger rhizome sizes as shown in **Fig. 6**. The machine capacity was higher for larger size ginger rhizomes and low for small size rhizomes for UG I and UG II respectively. The machine capacity was higher for UG II than UG I. Size of ginger rhizomes has a highly significant effect on the machine capacity while feed rate has significant effect as presented in **Table 2**.

The splitting efficiency increased with increasing ginger size with UG I consistently higher than UG II for large, medium and small for the speed levels evaluated is presented in **Fig. 7**. The highest splitting efficiency was obtained with large rhizomes size of UG I. The ANOVA shows a highly significant effect of variety and size on splitting efficieny (**Table 2**).

The percent dust increased with decreasing ginger rhizomes size

Fig. 4 Effect of Speed on Percent Dust



Use kg/h (vertical axis)

Fig. 5 Effect of Speed on Percent Injured

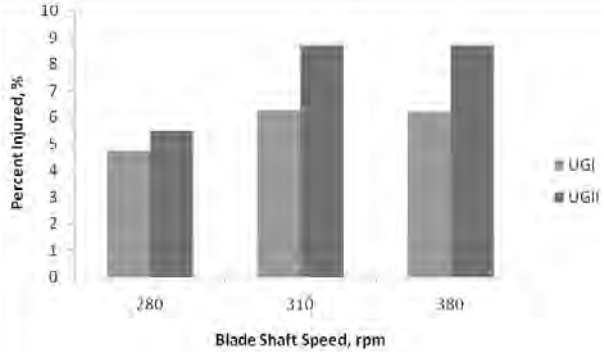
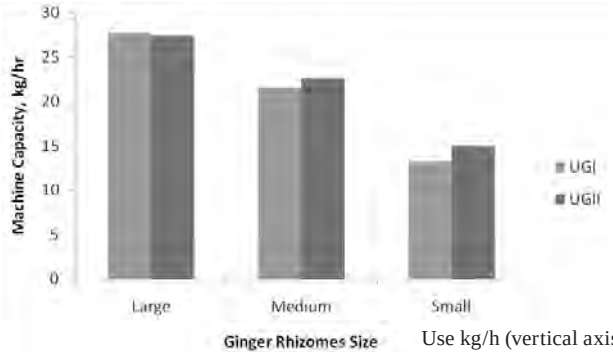
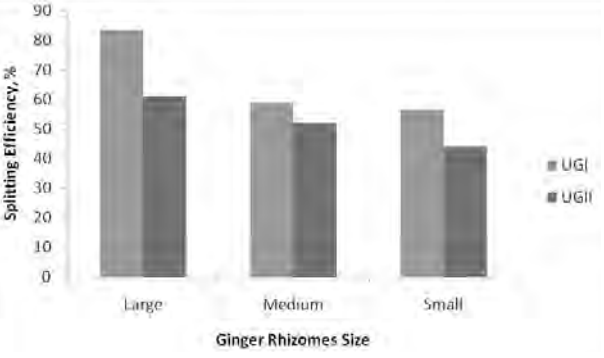


Fig. 6 Effect of Ginger Rhizomes Size on Machine Capacity



Use kg/h (vertical axis)

Fig. 7 Effect of Ginger Rhizomes Size on Splitting Efficiency



(**Fig. 8**). The percent dust was low with larger ginger rhizomes and high with small ginger rhizomes for UG I and UG II respectively. Umudike ginger I produced consistently higher dust than UG II for large, medium and small ginger rhizomes respectively.

There was increasing percent injured with increase in ginger rhizomes size as presented in **Fig. 9**. The highest percent injured was observed for UG I and UG II with large ginger rhizome sizes. The lowest percent injured for both ginger varieties was also observed for small ginger rhizome sizes. Umudike Ginger I consistently had high percent injured than UG II for the large, medium and small sizes respectively. **Table 2** shows the analysis of variance of size on percent injured. There was a highly significant effect of variety on percent injured.

Conclusions

A motorized ginger rhizomes splitting machine based on sawing principle with serrated blade was developed. The following conclusions could be made:

1. The splitting efficiency decreased with increasing blade shaft speed above 280 rpm.
2. There was increase in percent dust and percent injured with increasing speed.
3. There was an increase in machine capacity, splitting efficiency and percent injured with increase in ginger rhizomes sizes.
4. The percent dust increased with decrease in ginger rhizomes size.
5. There was a highly significant effect of speed, variety on machine capacity, splitting efficiency and percent dust.
6. There was highly significant effect of size on machine capacity, splitting efficiency and percent injured.

Acknowledement

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Fig. 8 Effect of Ginger Rhizomes Size on Percent Dust

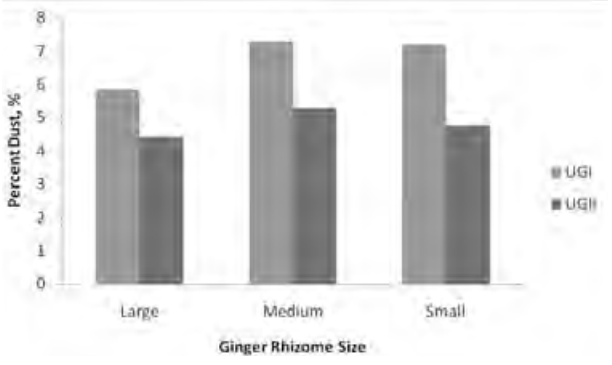
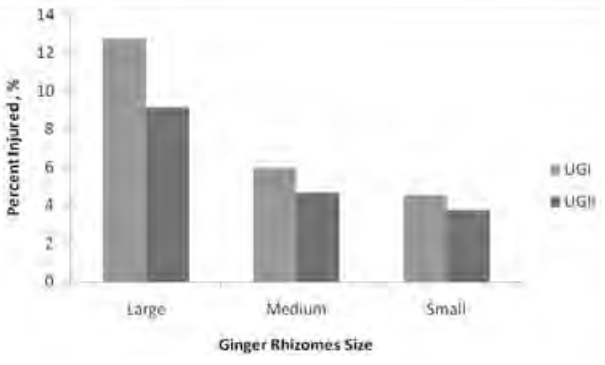


Fig. 9 Effect of Ginger Rhizomes Size on Percent Injured



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NEWS

◆ IAMFE celebrates its 50th year in Norway

IAMFE (International Association on Mechanization of Field Experiments) held ceremony for its 50th anniversary and meeting at the Norwegian University of Life Sciences in Ås, the neighbouring city of Oslo, Norway on July 27th 2014. There was an exhibition for various historical machines used for 50 years for field experiments. IAMFE was founded in 1964 by Dr. Egil Øyjord at the Department of Agricultural Engineering of the Agricultural University of Norway. There are many agricultural experiment stations all over the world. All these stations investigate potential improvements to food production and agribusiness day and night. This hard work can be seen in higher productivities of crops and food sources for growing population. To investigate the potential improvements, efforts and energy are needed to be devoted and in the past, these were by human hands. Dr. Øyjord took notice of this hard work. He appealed for the necessity of farm mechanization to speed up the research and established IAMFE. The research has been collaborated with various organizations in the world for 50 years, and this lead to advancing of various studies and researches. At present, Dr. Øyjord is retired and is Honorary President of IAMFE and Dr. Shang Shuqi of the Qingdao University is serving as President. At this ceremony, Dr. Øyjord's daughter received the award and the commemoration in his honour.

Dr. Shang Shuqi

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Performance Evaluation of Paddy Straw Pasteurizer for Mushroom Cultivation

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Abstract

Paddy straw found to be one of the most efficient substrate for mushroom cultivation. Since the straw is mainly composed of lignin and cellulose that are degraded enzymatically in the course of substrate utilization by the fungus. The edible mushrooms utilize lignocellulose as a source of carbon for their growth through enzymatic degradation. But very often a number of competitive fungi are found to grow in paddy straw during mushroom cultivation which affects the spawning rate, mycelium growth and mushroom yield. Hence pasteurization is an important process to prevent the growth of these competitor fungi and make the substrate more favourable for mushroom mycelia growth. For effective paddy straw pasteurization, a pasteurizer was developed and its performance was evaluated. Straw was pasteurized after soaking in normal water and without soaking. Different temperature-time combinations and compression levels was used. Substrate obtained was used to cultivate three commonly cultivated mushroom species in India. *Hypsizygus ulmariusn*, *Pleurotus Sajor-caju* and *Calocybe Indica* offered highest yields of 290.7 g/kg substrate with biological efficiency of 79.6 %, 254.1 g/kg substrate with biological efficiency of 69.6 % and 342.3 g/kg substrate with biological efficiency of 93.8 %, respectively. Contamination was absent when straw was pasteurized at 80 ºC for 2 h under maximum compression.

Key words: Paddy straw pasteurizer, substrate disinfection, substrate pasteurization, mushroom machinery, mushroom cultivation, substrate preparation.

Introduction

In India, around 136.5-150 MT of paddy straw is produced annually. Approximately 85-95 MT of paddy straw is disposed as waste (Anonymous, 2010). Hence, paddy straw is one of the most abundantly available agricultural waste and its usage as substrate for mushroom cultivation very common. Mushroom cultivation is one of the efficient methods for bioremediation of the

Nomenclature			
g/kg	gram per kilogram	mm	millimetre
%	percent	W	watts
h	hour	m^2	square metre
ºC	degree centigrade	ppm	pods per million
MT	million tonnes	BE	biological efficiency
C : N	carbon: nitrogen	L	litre
min	minutes	cm	centimetre

large quantity of agricultural wastes produced every year (Stamets, 2000 and Das and Mukherjee, 2007). It is known that straw with high lignin and cellulosic contents offers a better mushroom yield. Since the nutrient composition of substrate is one of the major factor which limit the formation of mycelium colonization of cultivated mushrooms (Tshinyangu *et al*., 1995).

The paddy straw is mainly composed of carbohydrate components such as hemicelluloses, cellulose, and lignin (Lee, 2004b). The high amount of carbohydrate and other components such as silica and ash makes paddy straw rich in C:N ratio. Ginterova and Maxianova (1975); Wood and Leathurn (1983) reported that the enzymes from basidiomycetous fungi involved in lignocelluloses degradation are involved in break down the cellulose to simpler molecules. Kurtzman (1975) and Park *et al*. (1975) have reported several studies on cultivating different mushrooms in different organic wastes and found yield on paddy straw was slightly higher than all other organic wastes used in those studies. One of the major problem in mushroom cultivation is weed fungi are found to grown in paddy straw during mushroom cultivation, among these, Coprinus cinereus is very common. Sometimes growth of mycelium is seriously hampered by the activity of competitor moulds like Trichoderma harzianum and Coprinus comatus (Pandey and Tewari, 1993).

Hence pasteurization is an important process that allows the microbial decomposers to loosen the tensile strength of paddy straw. This process also prepares the paddy straw to be easily colonized by mycelia. It also arrests the growth of competitor fungus and simultaneously makes the substrate more favourable for mushroom mycelia growth (Quimio, 1993). If pasteurization is not effective, then all further processes will be affected right from inoculation/spawning to mushroom yield. It was reported that green mould competes with the mycelia for space, nutrients which causes chemical changes in substrate, thus hampers mushroom development (Chang and Miles 1989).

There have been several attempts for substrate disinfection by using conventional equipment's like plastic and metal drums fitted with electrical heating coils, pressure cooker, autoclave, bulk pasteurization using steam and chemical pasteurization. Kurtzman (1979c) reported a method of placing substrate in beds inside room, once the temperature is increased by self-heating, steam was added until both air and substrate temperature reaches 60 ºC with a holding time of four or more hours. (Zadrazil, 1980; Abe *et al*., 1992; Mansur *et al*., 1992, and Maziero *et al*., 1992) showed disinfection can also be done by injecting vapour into chambers or tunnels containing packed substrate and pasteurization time was varied as a function of temperature. Stamets, (1993); Balasubramanya and Kathe, (1996) followed immersion of substrate in hot water and Zanetti & Ranal, (1996) sterilized the substrate in autoclave. Similarly Kurtzman (2010) proposed two methods, pasteurization with hot water at 60 ºC and holding for 30 to 60 min in ordinary steel drum and second mixer method where water at approximately 63 ºC is poured over paddy straw. Draining out excess water after pasteurization was found difficult when fibres and many other wastes were put into excess water, consequently substrate hold too much water and insufficient air.

Nevertheless, all these conventional methods associated with drawback such as longer pasteurization time, heat and energy loss, difficulties in handling of hot straw after pasteurization for cooling and draining out excess water. Contamination was observed due to corrosive nature of pasteurizing drum and exposure of pasteurized

Figs. 1, 2 & **3** Different view of developed pasteurizer

Fig. 1 Front view tilted

Fig. 2 Front compressed view

Fig. 3 Inner view of drum

straw to the open air for long time. Therefore, the present study was conducted with the aim of developing a pasteurizer specifically meant for paddy straw pasteurization in hygienic condition for optimal mushroom yield and reduced pasteurization time and operating cost.

Material and Methods

Developed Pasteurizer

The paddy straw pasteurizer (**Figs. 1, 2** & **3**) was developed and fabricated in workshop of Agricultural Engineering Section, Indian Institute of Horticultural Research (IIHR), Bangalore. The developed machine consists of: Stainless steel (grade 316) pasteurizing drum with glass wool insulation. The drum length was divided into three sections which included bottom coil section containing electrically heated coils and temperature sensor, middle pasteurizing section and top free board. Drum was then fixed to a rigid frame equipped with wheels for portability. A compresson unit was mounted above the drum so as to compress the straw bed thickness inside the drum before pasteurization in order to reduce the water, energy and time required for pasteurization. For loading and unloading, the drum shaft was mounted with manually operated gear box assembly which can tilt the drum to required angle. Steps were provided on one side of machine so a person can climb over to operate the compresson unit. Time-temperature controlling unit was also installed to maintain required temperature for definite time period. For pasteurization of paddy straw KRH^{-1} (Karnataka Rice Hybrid) variety was collected from nearest village farmer.

Substrate Preparation

Paddy straw of Karnataka rice hybrid (KRH^{-1}) variety were collected and chopped into 2.5-5.0 cm pieces and 25 kg chopped straw was filled by hand pressing into pasteurizer drum. Straw bed thickness was compressed to required thickness by operating compression unit as shown in **Figs. 4, 5** & **6**. Water was then added until water appeared few centimetres just above the top level of the compressed straw bed and allowed for overnight soaking. Power supply was switched on and the pasteurizing temperature and time was set in the time-temperature control unit. Once the temperature of water reached 80 ºC then this temperature was maintained for 2 h. At the end of pasteurization the gate valve was opened to drainthe water and then screw press was rotated to compress the straw to maximum level to drainexcess water present in pasteurized straw. The drum was tilted to bring it to the horizontal position using rotating handle of the gear box. Hot pasteurized straw was then directly unloaded on a perforated tray and spread uniformly to cool it to room temperature and also to reduce moisture content around 60 % which was optimal for bag filling.

Mushroom Cultivation

The spawn of three varieties mushroom were collected from mushroom laboratory of Indian Institute of Horticultural Research (IIHR). One kg of pasteurized straw having moisture content around 60 % was then filled to polypropylene bags (150-gauge thick, 300 × 355 mm) and spawn dose of 5 % (by the straw wet weight) was followed as described by Pani and Das (1998). The filled bags were kept in the incubation (25 ± 2 ºC) until full colonisation by mycelia was attained. The environmental conditions during cropping were 25 ± 2 ºC temperature, 75 % ± 5 % humidity, and 8 h electrical lighting with 125 W mercury lamp in 15 m^2 cropping room of mushroom laboratory of IIHR. After spawn running period of 20-25 days the bags were opened and water was sprayed on substrate bags twice a day in the morning and evening. After three days the first

Figs. 4, 5 & **6** Paddy straw compressed to different levels before pasterization

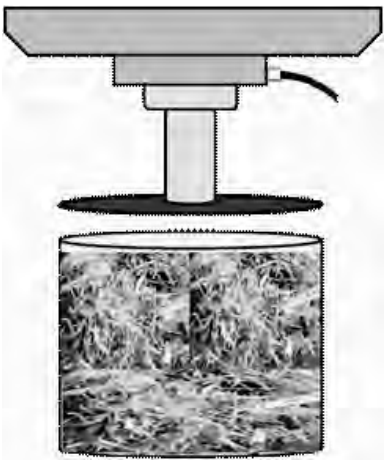


Fig. 4 Loose filled

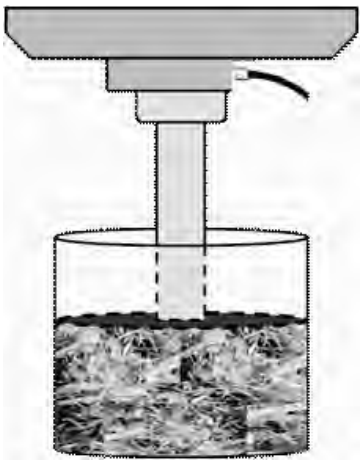


Fig. 5 50 % compressed

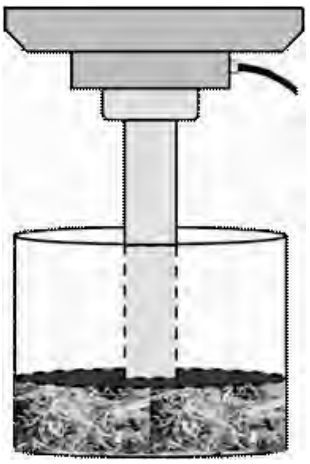


Fig. 6 Maximum compressed

fruiting was observed and matured mushrooms were harvested and data was recorded.

Comparative Performance Study of Paddy Straw Pasteurizer with Conventional and Chemical Pasteurization

For comparing the performance of developed pasteurizer with conventional method, the pasteurization of straw after soaking (80 ºC for 2 h) with loose filling (**Fig. 4**) was considered as conventional/control method. For chemical pasteurization, the paddy straw pieces of 2.5-5.0 cm were soaked for 18 h in an aqueous solution containing 75 ppm Bavistin and 500 ppm Formaldehyde. Straw was taken out after 18 h of soaking and chemically sterilized straw was spread on perforated tray or on raised wire mesh frame to drain out excess water and also to reduce moisture content around 60 % inside the chamber where bag filling and spawning were to be done (Saritha and Meera Pandey, 2010).

Bio-efficiency of Mushroom

Fully matured mushrooms were harvested prior to watering and fresh weight was determined immediately and each bag was allowed for 2-3 cropping. Bio-efficiency of mushroom was calculated by using formula as recommended by Chang and Miles (1989).

Bio-efficiency (%) = {Fresh weight of mushroom (g) / Dry weight of substrate (g)} × 100

The three different mushrooms, i.e. Calocybe Indica, Hypsizygus ulmariusn and Pleurotus Sajor-caju were cultivated from pasteurized straw (after soaking overnight and without soaking) under different compression levels with three pasteurization temperature and time combinations. The moisture content (%) of pasteurized straw before spawning, number of contaminated bags per batch was also recorded. The yield of all three mushroom varieties from pasteurized straw after soaking and without soaking are presented in Graphs.

Statistical Analysis

The experiment was conducted using ten replicates of mushroom yield which were subjected to analyses of variance (one-way ANOVA) at the 5 % level using the Statistical Package for Social Sciences (SPSS) Program 16.0 Version (SPSS. 2007). The average mushroom yields were compared within the treatments and between the compression levels.

The effect of compression during pasteurization of paddy straw on mushroom yield of Hypsizygus ulmariusn, Pleurotus Sajor-caju and Calocybe Indica were analysed by comparing among means was done using Least Significant Difference (LSD) test. LSD was conducted at a 5 % level of probability, where significance was indicated by F-test (Gomez and Gomez, 1984).

Results and Discussions

Three different commercially cultivated varieties of mushroom were cultivated to test the efficiency of pasteurization and from each batch of pasteurized straw ten bags of three different mushroom varieties (Hypsizygus ulmariusn, Pleurotus Sajor-cajuand Calocybe Indica) were cultivated in the months of April to May for evaluating the developed pasteurizer.

Yield of Hypsizygus Ulmariusn from Pasteurized Straw with and without Soaking

Data (**Figs. 7** & **8**) revealed that the mushroom yield was significantly affected by different compression levels. The yield obtained from straw pasteurized under maximum compression (**Fig. 6**) was found to significant (P > 0.05) when compared to the yield obtained from straw pasteurized under loose filled and 50 % compression levels at 80

Fig. 7 Hypsizygus ulmariusn yield from paddy straw pasteurized after soaking

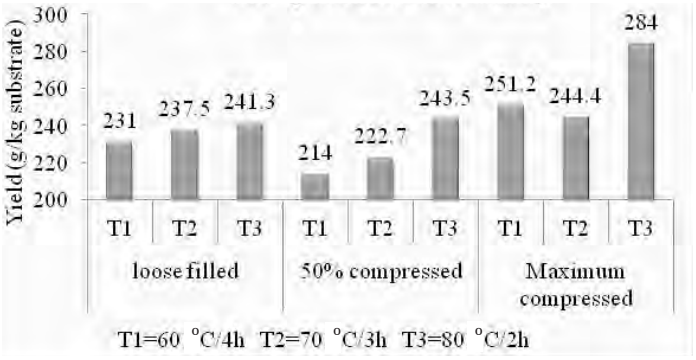


Fig. 8 Hypsizygus ulmariusn yield from paddy straw pasteurized without soaking

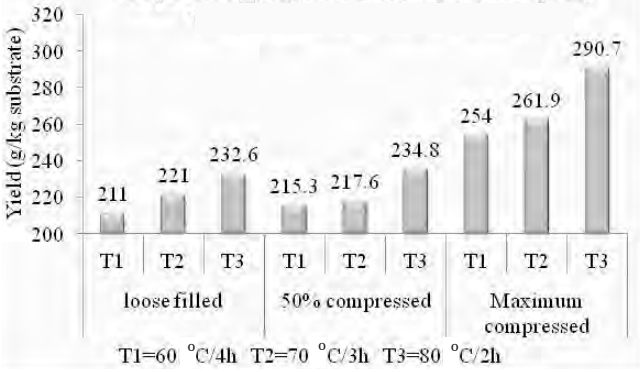


Table 1 Statistical result for three varieties mushrooms yields obtained from straw pasteurized after soaking and without soaking

Mushroom variety	Hypsizygus ulmariusn				Pleurotus Sajor-caju			Calocybe Indica		
Sources of variation	df	M.S	F	sig	M.S	F	sig	M.S	F	sig
Treatment	1	19.08	0.023	0.887*	53.52	0.929	0.39*	56.427	1.33	0.313*
Error	4	831.13			57.61			42.412		
Total	5									

At 5 % level of significance *LSD, P > 0.05

ºC for 2h.

The highest yield (290.7 g/kg substrate and 79.6 % BE) on fresh weight basis was obtained from straw pasteurized (without soaking) at 80 ºC for 2 h under maximum compression (**Fig. 7**). This followed by straw pasteurized (after soaking) at 80 ºC for 2 h under maximum compression gave second highest yield (284 g/kg substrate and 77.2 % BE), (**Fig. 8**).

Decrease in yield and biological efficiency could be explained by the fact that soaking straw overnight reduced the production potential of substrates due to the variations in straw's physical and chemical properties and nutritional composition. The partial destruction of the lignin-cellulose bonds would favour substrate contamination when pasteurization is done at low temperature (60 ºC 4 h) (Bahukhandi & Munjal, 1989; Stamets, 1993; Balasubramanya & Kathe, 1996; and Sturion & Ranzani, 1997). As thecontamination was absent when straw pasteurized under maximum compression at 80 ºC for 2 h, this could be due the fact that pasteurization with maximum compression had better heat conduction through compressed straw which lead to effective breakdown of lignin-cellulosic bonds and resulted in more availability of cellulose (Sturion & Oetterer, 1995a) and also reduced most of the competitor moulds like Trichoderma harzianum and Coprinus comatus which were commonly found in paddy straw (Saritha and Meera Pandey, 2010).

Yield of Pleurotus Sajor-Caju from Pasteurized Straw with and without Soaking

The P. Sajor-caju showed numerically superior results for biological efficiency and yield from straw pasteurized (80 ºC for 2h) under loose filled and 50 % compression level, as seen in **Fig. 9** & **10**, although with differences not significant (p > 0.05). However, in case of pasteurization under maximum compression (**Fig. 6**) the mushroom yield results were significantly different.

The data (**Fig. 9**) revealed that the highest yield (254.1 g/kg substrate with B.E of 69.6 %) was obtained from straw pasteurized (without soaking) at 80 ºC for 2 h under maximum compression. And followed by straw pasteurized (after soaking) at 80 ºC for 2 h under maximum compression gave second highest yield ((246.3 g/kg substrate with B.E of 71.4 %), (**Fig. 10**).

The decrease in yield in other methods was due to the fact that soaking straw overnight may have altered the physical and chemical properties and nutritional composition. The effects of physical and chemical properties of substrates on yield and biological efficiency have been investigated in Agrocybe aegerita, Volvariella volvacea, Pleurotus spp., Lentinula edodes and Ganoderma lucidum (Philippoussis, 2001) and these results compare favourably with the findings of Shayamal *et al*., 2011. Contamination

Fig. 9 Pleurotus Sajor-caju yield from paddy straw pasteurized after soaking

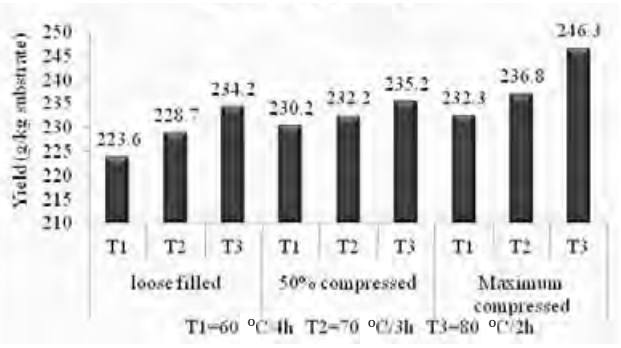
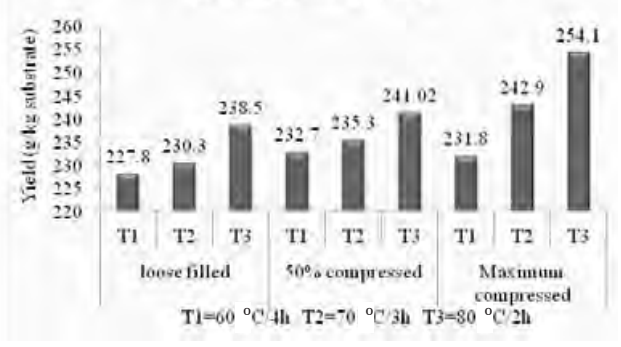


Fig. 10 Pleurotus Sajor-caju yield from paddy straw pasteurized without soaking



was absent in both the treatments because pasteurization (80 ºC for 2 h) at its maximum had better heat conduction through compressed straw that could kill most of the competitor moulds like Trichoderma harzianum and Coprinus cromatus (Saritha and Meera Pandey, 2010). High temperature pasteurization could make cellulose more available due to complete destruction of lignin-cellulose bonds (Sturion & Oetterer, 1995a). Hence the harmful microorganisms present in the compost were eliminated during the high temperature pasteurization (Bononi *et al.*, 1995).However if temperature exceeds to sterilization condition, then it is likely that beneficial organisms will be killed (Kurtzman, 2010).

Yield of Calocybe Indica from Pasteurized Straw with and without Soaking

The yield (342.3 g/kg substrate with BE of 93.8 %) was higher in response to paddy straw pasteurized (without soaking) under maximum compression (**Fig. 11**) was higher but not significantly different from straw pasteurized after soaking (334.4 g/kg substrate with BE of 91.6 %) at 80 ºC for 2 h (**Fig. 12**). But these highest yields from both the cases were found significantly different ($P > 0.05$) compared to straw pasteurized under loose filled and 50 % compression at 80 ºC for 2 h. These finding are in contradiction to the report of Krishnamoorthy and Muthusamy, 1997. The important observation of the mushroom yield variation was further supported by the previous observation of Villaceran *et al.*, 2006. The varied production potential of soaked substrates may have been due to the variations in their physical, chemical properties and nutritional composition. In addition to this, the textural properties of soaked and pasteurized straw were found unhealthy for mycelium growth compared to straw pasteurized without soaking, hence it was also reported that milky mushroom (Calocybe Indica) required somewhat dry and sturdy substrate for better anchorage and growth (Sherin *et al.*, 2004).

The microbial contamination was not found, which might be explained due to fact that pasteurization (80 ºC for 2h) and maximum compression offered better heat conduction through compressed straw which supressed the most of the competitor moulds like Trichoderma harzianum and Coprinus comatus. The high temperature pasteurization and sterilization of straw will lead to effective breakdown of lignin-cellulose bonds and enhances the availability of cellulose which is important in reducing the contamination during cultivation process (Sturion & Oetterer, 1995a).

The yields of all the three mushroom varieties cultivated (Hypsizygus ulmariusn, Pleurotus Sajor-caju and Calocybe Indica) from pasteurized paddy straw after soaking and without soaking were found maximum, when straw pasteurized at 80 ºC for 2 h at maximum compression (**Fig. 6**). But soaking before pasteurization was found to be a time and labour consuming process, hence direct pasteurization at 80 ºC for 2 h with maximum compression (**Fig. 8, 10** & **12**) was also able to produce similar yields as those of conventional methods with reduced time and labour requirements.

Nevertheless, the variation in mushroom yield obtained from substrate formed from different pasteurization temperature-time combination under different compression levels might have been due to the variations in their nutritional composition and physical properties, physiological factors required for cultivation. Controlled and semi-controlled conditions like quality of span used, variation in environmental conditions (temperature, relative humidity and light intensity) and climate change. Poor growth of mycelia and low yield of mushroom in few substrates might have also

Fig. 11 Calocybe Indica yield from pasteurized paddy straw after soaking

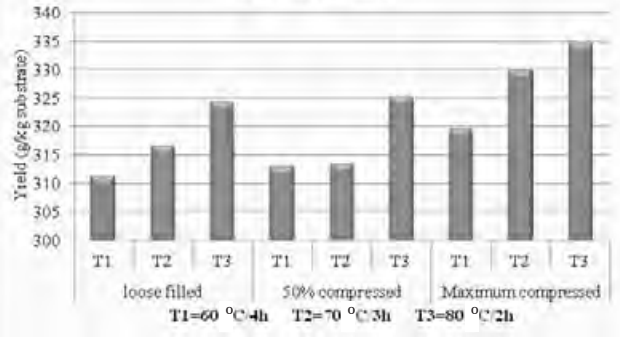
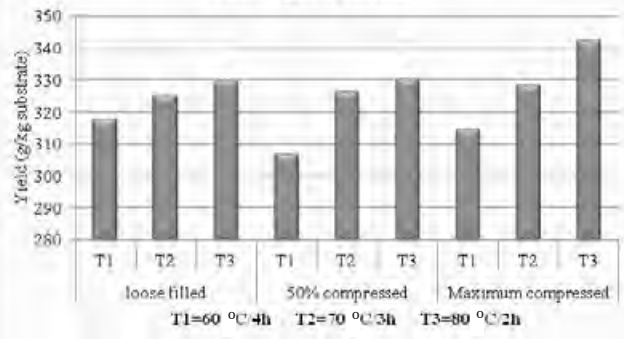


Fig. 12 Calocybe Indica yield from pasteurized paddy straw without soaking



varied depending upon bulk density of substrate, amount of aeration, water holding capacity of substrate, hygienic condition maintained, time taken for formation of pinheads, maturation of fruiting bodies, period between flushes, number of flushes and yield etc. It was seen that soaking of straw overnight alters the physical properties of straw, when this straw used as substrate after pasteurization had more bulk density with poor water holding capacity and reduced aeration through substrate during mycelium running period which is mandatory. Similar observations were stated by the findings of Zhang *et al*., 2002. It has been reported that the over compacted substrate inside the bags will restricts the air exchange between void spaces of substrate and head space thus alerts the CO_2 and O_2 levels which plays an important role in colonization of mycelium. The role of CO_2 and O_2 on growth and development of mushrooms have been reported in other studies by Jenson (1967) and Donoghue and Denison (1995). Similar findings were reported by Pani (2010) suggesting that the proper exchange of gases through substrate is very much essential for the mycelium to acquire more oxygen and to remove harmful volatiles and respiratory gases. The rate of mycelial colonization and sporophore production will be limited due to poor gas exchange rates and high water holding capabilities. Lanzi (1986) reported that when cold water was used for soaking of straw before heat was applied. The cold water was repelled by the natural waxy surface of straw, and it took many days to wet the straw meanwhile the straw was damaged by harmful microorganisms during wetting. Kurtzman (2010) found that adding dry substrate into hot water (> 60 ºC) straight away melts the natural waxy coating on straw thus enabling the hot water to penetrate rapidly and wet the dry substrate. The pasteurization begins as soon as the substrate contacts the water there by reducing the chances for growth of harmful organisms. Based on these observations it was considered that straw soaked overnight before pasteurization in present study might have varied the substrate properties. Subsequently, the substrate which was directly pasteurized without soaking (wetting), the natural waxy layer would have been melted thus allowing hot water to penetrate and disinfect effectively resulting in little higher mushroom yields. **Table 1** shows the statistical results for mushroom yields obtained from straw pasteurized (after soaking and without soaking) at 80 ºC for 2h under different compression levels. The mushroom yields from straw pasteurized without soaking was significantly ($P > 0.05$) varied from yields obtained from straw pasteurized after soaking for all three mushroom varieties cultivated.

Table 2 Comparative performance of paddy straw pasteurizer with conventional and chemical pasteurization

Observation	Pasteurization method		
	Chemical	Conventional (control)	Developed pasteurizer
Variety	Hypsizygus ulmariusn	Hypsizygus ulmariusn (80 ºC for 2h)	Hypsizygus ulmariusn (80 ºC/2h)
Number of bags made and variety (kg substrate/bag)	20	20	20
Number of bags contaminated	8	4	0
Average yield per bag (g/kg substrate)	182.9c	241.3b	290.7a
Bio-efficiency (%)	48.6	62.7	79.6

Table 3 ANOVA one way classification

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	58,183.817	2	29,091.908	4.678E3	0.00
Within Groups	167.925	27	6.219		
Total	58,351.742	29			

At 5 % level of significance

Comparative Performance of Paddy Straw Pasteurizer Against Conventional and Chemical Pasteurization

The results of Hypsizygus ulmariusn mushroom yield from chemical, conventional and developed pasteurization methods are presented in **Table 2**. The contamination incidence was very high (40 %) in chemical method compared to conventional method (20 %) and developed method (zero percent). Developed hot water pasteurization method (80 ºC for 2 h) was able to prevent contamination completely compared to conventional (80 ºC for 2 h) and chemical pasteurization methods. The yields from developed and conventional method were significantly higher (290.7 and 241.3 g/kg substrate, respectively) followed by chemical method (182.9 g/kg substrate) (**Table 2**). These results were also in conformity with Saritha and Meera Pandey 2010. The average yield obtained from chemical sterilization and conventional method ($P > 0.05$ in **Table 3**) significantly decreased by 17 % and 37.1 % respectively, compared to developed hot water pasteurization method. This was due to the fact that the hot water pasteurization aids in softening the straw texture associated with breakdown of lignin-cellulosic bond, while chemical pasteurization alters the physical and chemical properties of straw, similar findings were reported by Saritha and Meera

Pandey, 2010. According to Balasubramanya & Kathe (1996), the microorganism species that competed with Pleurotus sp. fungi Penicillium sp. and Trichoderma sp., which could be still available even after pasteurization because of partial destruction of lignin-cellulose bonds favouring substrate contamination. Hence pasteurization with hot water at high temperature could make cellulose more available (Sturion & Oetterer, 1995a). Thus, contamination of the pasteurized substrate could have occurred because of the temperature and time used during pasteurization, exposure of substrate to open air before spawning and also due to inappropriate management or the mycelium becomes weaker after successive cultivations (Ferreira, 1998). Nevertheless, High productivity and biological efficiency of mushroom with the absence of contamination from substrate prepared by developed pasteurizer which makes it a promising ideal technology for mushroom growers.

Conclusion

The developed paddy straw pasteurizer was evaluated for pasteurization of paddy straw to cultivate three different mushrooms (Hypsizygus ulmariusn, Pleurotus Sajorcaju and Calocybe Indica). Under given set of conditions followed, the highest mushroom yield of Hypsizygus ulmariusn, Pleurotus Sajor-caju and Calocybe Indica (290.7 g/kg substrate with B.E of 79.6 %, 254.1 g/kg substrate with B.E of 69.6 % and 342.3 g/kg substrate with B.E of 93.8 %, respectively) without any contamination when un-soaked straw pasteurized at 80 ºC for 2h with maximum compression.

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Axial Flow Pre-Cleaner for on Farm Cleaning of Cotton

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Abstract

A single cylinder cotton pre-cleaner based on axial flow principle was designed and developed. The developed axial flow pre-cleaner consists of different assembly's viz. cylinder, grid bar, top cover, feeder, and mainframe and power drive assembly. The pre-cleaner of 1,200 mm cylinder length and overall peripheral cylinder diameter of 443.4 mm was fabricated. It was observed that the principle of axial flow could be effectively used for pre-cleaning of cotton. The machine was found to remove effectively the large trash particles, sand, dust, kawadi etc. The capacity of the machine was found to be 650 kg/h. The cylinder with diameter of 203.2 mm and spike length of 114.6 mm was found optimum. The better cleaning efficiency and optimum output was observed at cylinder speed of 225 rpm. The cleaning efficiency of the machine was found between 30-40 %. The machine found to bring down the trash content by about 0.8-1.5 %. The fibre quality parameters viz. fibre length, uniformity ratio, micronaire and strength were unaffected by the axial flow pre- cleaner. The improvement in the colour grade of the cotton was observed. The cost of operation per hour and per tonne was observed to be Rs. 44 and Rs. 67.5 respectively. Additional income to farmer per tonne was found to be Rs. 540. It was observed that axial flow pre-cleaner could be effectively used for on farm cleaning of cotton to enhance farm income.

Introduction

The Indian cotton are considered to be trashy despite being hand picked and being contaminated by wide range of impurities gathered during post harvest handling till it reaches the spinning mills. In the process of picking, laborers pick the cotton with large amount of trash such as leaves, stems, bracts and immature and unopened bolls. The cotton is sold in the market based on its grade. The market value of cotton is decided by the quality and purity of its fibres. The trash content in the cotton is the predominant parameter in deciding the value of the cotton. Thus fetching good price in the market, the baled cotton should contain minimal trash and be free from contamination (Patil *et al*., 2006). Due to high trash content in the cotton farmer fetches lower prices. The farmers may realize high prices for their cotton, if they clean it and sell it into the market. But the suitable pre-cleaner which can be used by the farmers is not available.

If pre-cleaning is not done trash particles are made to adhere to the fibres during the high pressure baling process. Subsequent removal of trash in the blow room at spinning mills becomes difficult, expensive and detrimental to fibre quality. Pre-cleaning is necessary to improve gin stand performance and lint quality. Cylinder cleaners are used for removing finely divided particles and for opening and preparing the seed cotton for the drying and extraction processes (Mayfield et. al., 1983). The spiked cylinder pre-cleaners works on the principle of feeding the cotton longitudinally i.e. along the length of the cylinder. The cleaning efficiency of cylinder pre-cleaner mainly depends on the number of cylinder employed. Use

of pre-cleaners in Indian ginning industry is increasing day by day.

Cylinder cleaners are either inclined cleaners or horizontal cleaners depending on the arrangement of the cylinder. Inclined pre-cleaners are currently manufactured in widths of 1.2-2.4 m with rated capacities of 3.5-6.0 tonne seed cotton/h. Inclined pre-cleaners are employed with 4 to 6 cylinders depending on the cleaning efficiency required. They are of high capacity, costlier and require more power. These are not affordable to farmers.

The trash removal efficiency of cylinder cleaners is generally low. However they are not used alone but are used in combination with other machines. Studies using both machine picked and machine stripped cotton have shown that the total trash removal efficiency of a six cylinder inclined cleaner with grid rods generally ranges from 10-40 % (Cocke, 1972; Read, 1972; Baker *et al.*, 1982). These efficiencies, however, were based on the test cotton's total trash content. Fine trash removal efficiencies as high as 50-55 % has been reported for both grid –rod and screen type inclined cleaners when processing stripped and picked cotton (Laird *et al.*, 1984, Anthony 1990). Efficiencies are highest for high trash content cottons (Franks and Shaw. 1959).

Cleaning machinery is subjected to considerable wear from the large volumes of trash and soil particles contained in the seed cotton. Also seed cotton occasionally contains rocks, scrap metal, large woody debris or other foreign objects that can damage various machine components. The removal of trash reduces wear and tear of gin parts (Baker *et al.*, 1994). Fibre quality remains unaffected by the use of pre-cleaner (Shukla *et al.*, 2006).

These present pre-cleaners which are bigger in size and more in capacity are not feasible for the on farm use. The farmers need compact pre-cleaners with much lesser output and with reduced energy consumption. The pre-cleaning machine can be made more compact and suitable to farm use with lesser power requirement by employing the principle of axial flow feeding of cotton to the cylinder. Therefore a single cylinder cotton pre-cleaner based on axial flow principle for the use of farmers was developed.

Materials and Methods

A single cylinder cotton pre-cleaner based on axial flow principle was designed and developed at the Ginning Training Centre of Central Institute for Research on Cotton Technology (CIRCOT), Nagpur. The three dimensional drawings and two dimensional draftings of each machine component, subassemblies and whole machine were prepared. The single cylinder axial flow pre-cleaner was fabricated and tested. The performance of the machine was evaluated to find out the applicability of the principle of axial flow for pre-cleaning of cotton. The developed machine was tested at different cylinder speeds and cottons. The cylinder speed was maintained between 175-400 rpm with the help of variable frequency drive. The output capacity, trash removal efficiency, reduction in trash content and effect on cotton fibre quality was studied. The cotton samples were tested on High Volume Instrument (HVI-900) for measurement of fibre quality parameters. The techno-economic feasibility of the developed machine was studied. The experimental trials were carried out to optimize the machine parameters as well their effect on cotton quality.

Independent Variables

The independent variables studied were as follows.

1) Grid size

Two grids were selected (1) Grid bar spacing 12 mm, (2) Grid bar spacing 10 mm.

Spacing between grid bars and spike tip: (1) 25 mm (2) 35 mm (3) 45 mm

2) Cylinder speed

Seven cylinder speed were selected: 175, 200, 225, 250, 300, 350 and 400 rpm.

3) Cottons

Three cotton varieties were selected: Cotton A, Cotton B and Cotton C.

4) Cylinder configuration

Three cylinder configurations were selected and named as C_1, C_2 and C_3 (**Table 1**).

Dependent Variables

The independent variables studied were output capacity, trash removal rate, cleaning efficiency, fibre quality and energy consumption.

Design and Fabrication

A prototype of cylinder type cotton pre-cleaner based on axial flow principle was designed and developed. The developed axial flow pre-cleaner consists of different assembly's viz. cylinder, grid bar, top cover, feeder and mainframe and power drive assembly. The pre-cleaner of 1,200 mm cylinder length and overall peripheral cylinder diameter

Table 1 Specifications of cylinder configurations

Parameter	C_1	C_2	C_3
Cylinder diameter (mm)	152.4	203.2	250.4
Spike length (mm)	140	114.6	89.2
Number of rows of spikes	6	8	10
Spikes on each cylinder	93	124	155
Spacing between spikes (mm)	75	75	75
Overall cylinder diameter (mm)	443.6	443.6	443.6
Cylinder length (mm)	1,200	1,200	1,200

of 443.4 mm was fabricated. Main components of a cylinder assembly were cylinder made out of a seamless pipe, cylinder shaft and spikes. Spikes were inserted in holes made on the periphery of the cylinder and welded from inside of the cylinder. The angular distance between each row was maintained properly. The adjustable semicircular grid made up of grid bars spaced at specified distance between the two grid bars was provided underneath the cylinder. Proper clearance was maintained between the tip of the spikes and the grid bars. The top cover assembly was developed and was provided with suitable inlets and outlets. Guide plates were fabricated and mounted at an inclination on the inside surface of the top cover to guide the movement of the seed cotton along the axis of the cylinder. Proper clearance was maintained between the tips of the spikes to the outer face of the guide plates. The feeder assembly consisting of counter rotating flighted roller was designed and developed for controlled feeding of the seed cotton. Main frame of the machine was fabricated out of channels and angles. The suitable drive arrangement was provided to drive the spiked cylinder and the feeder. The trash chamber was provided below the grid to collect the separated trash. Doors were provided on either side of the chamber for easy disposal of the trash. Schematic diagram of the developed axial flow cotton pre-cleaner is shown in **Fig. 1**. a pictorial view of the developed machine under testing is shown in **Fig. 2**.

Principle of Operation

Seed cotton was fed at one end of the spiked cylinder through feeder. It moved axially along the length of the cylinder as it rotated. The rotational motion of the cylinder draws the cotton inside and agitates it across the grid surfaces. The movement of the seed cotton along the axis of the cylinder was controlled by mounting specially designed guide plates on inside surface of top cover. These plates were mounted at a certain inclination to the axis at a certain distance such that it forms an open chamber. Seed cotton enters the machine at one end and moves from one to the other chamber along the axis of the same cylinder and gets discharged at the other end after cleaning. Foreign matter gets dislodged from the cotton by the agitating and scrubbing action of the cylinders and falls through grid bars provided underneath the spiked cylinder. The trash gets accumulated in the trash chamber. In case of axial flow cotton pre-cleaner if four guide plates are mounted on the machine, the seed cotton moves in a spiral path around and between the spiked cylinder and grid surfaces four times. It implies that in axial flow single cylinder pre-cleaner, cleaning efficiency would be equivalent to that of the four cylinder cleaner which employs the principle of feeding along the length of the cylinder.

Results and Discussion

Testing of the developed machine was carried out at Ginning Training Centre of Central Institute for Research on Cotton Technology, Nagpur. It was found working satisfactorily. It was observed that the principle of axial flow could be effectively used for pre-cleaning of cotton.

Optimization of Crop-Machine Parameters

The experimental trials were carried out to optimize the machine parameters as well their effect on cotton quality.

Optimizations of Grid Size

Spacing between grid bar and spike tip

Cleaning trials were conducted with different spacing between grid bar and spike tip. It was observed that at spacing of 35 and 45 mm, the cotton was getting accumulated under the cylinder which was found affecting the trash removal. The spacing of 25 mm was found to be optimum as cotton was not getting accumulated under the cylinder and trash removal was smooth. Therefore spacing of 25 mm between grid bars and spike tip was selected for further trials.

Spacing between Grid Bars

For optimiza-

Fig. 1 Schematic diagram of axial flow cotton pre-cleaner

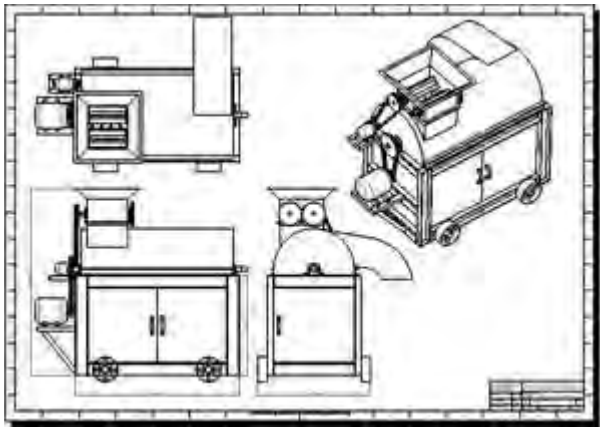


Fig. 2 A pictorial view while testing of axial flow pre-cleaner

tion of grid bar to bar spacing, spacing between grid bar and spike tip was maintained at 25 mm. The grid bar diameter was 10 mm. Three different types of grids were used. The 12 mm grid size observed to be oversized as the good cotton was passing through it along with the kawadi (immature and insect affected cotton) and trash. Another grid made up of a combination of 10 mm and 12 mm grid spacing was used. The grid with 10 mm spacing was used under first half portion of the machine and grid with 12 mm spacing was used under second half portion of machine from inlet to outlet respectively. In this grid also some good cotton was observed to pass through along with the trash. The 10 mm grid size was observed to remove the kawadi and trash effectively without allowing good cotton to pass through it. Therefore the spacing of 10 mm between the grids bars was selected for the further trials.

Table 2 Effect of cylinder speed on fibre quality parameters

Cylinder Speed, rpm	Fibre Length, mm	Uniformity Ratio, %	Fineness, Mic	Strength, g/tex
	Un-cleaned/ Cleaned			
175	29.5/29.4	46/46	3.4/3.4	20.9/21.4
200	28.4/28.1	47/47	3.3/3.2	20.8/20.2
225	29.6/29.8	46/46	3.2/3.4	23.0/22.8
250	28.9/29.6	46/45	3.7/3.6	23.0/23.4
300	28.6/29.9	46/47	3.7/3.7	21.0/21.5
350	27.6/28.9	47/46	3.5/3.5	21.1/22.2
400	29.2/30.4	48/47	3.6/3.5	23.7/23.6

Optimization of Cylinder Configuration

Three cylinder configurations were selected and named as C_1, C_2 and C_3. The output capacity, trash removal rate and cleaning efficiency was found out .The effect of cylinder configuration on fibre quality was determined. Three cottons as Cotton A, Cotton B and Cotton C and seven cylinder speeds were used.

Effect of Cylinder Speed on Output Capacity of Machine

The output capacity of the machine was found to increase with the increase in cylinder speed for all three cottons (**Fig. 3**, **Fig. 4** and **Fig. 5**). The output capacity was found to vary with cylinder configuration. Output capacity of the machine was observed better for cylinder C_2 compared to C_1 and C_3 (**Fig. 6**). Output capacity of machine with cylinder C_2 and for cotton C was observed to vary from 615 to 1,075 kg/h for the cylinder speed between 175-400 rpm. Similarly output capacity of machine with cylinder C_2 for cotton A and B was observed to vary from 655 to 1,029 kg/h. and from 600 to 1,108 kg/h respectively. The cylinder C_2 was found to be optimum in terms of output capacity of the machine. At cylinder speed of 225 rpm the output capacity of the machine was found between 650-758 kg/h for different cottons.

Fig. 3 Effect of cylinder (C_1) speed on output capacity

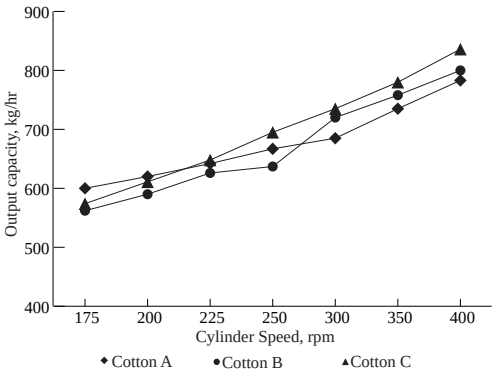


Fig. 4 Effect of cylinder (C_2) speed on output capacity

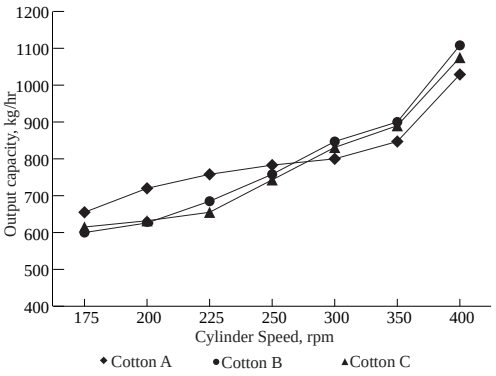


Fig. 5 Effect of cylinder (C_3) speed on output capacity

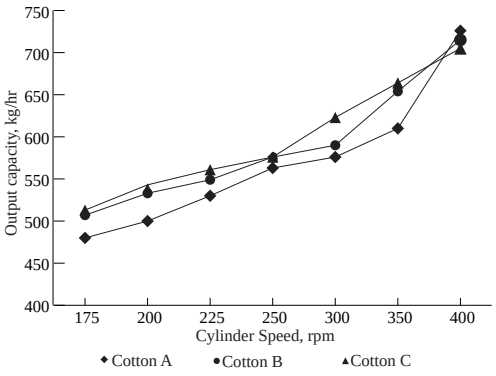
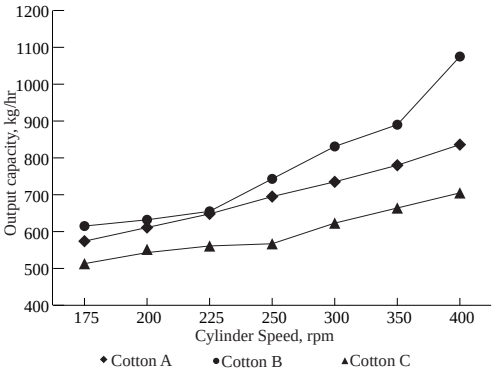


Fig. 6 Effect of cylinder speed and configuration on output capacity for cotton C



Effect of Cylinder Speed on Trash Removal

The machine

Table 3 Effect of cylinder speed on short fibre content and colour grade

Cylinder speed (rpm)	SFI (%)	Rd	+b
	Un-cleaned/Cleaned		
175	8.6/7.8	84.1/84.6	9.17.9
200	9.6/7.8	84.2/85.3	8.4/6.8
225	8.3/7.8	83.0/84.6	8.9/7.9
250	7.6/7.4	84.6/84.8	9.4/8.1
300	8.6/6.7	82.1/84.0	9.4/8.6
350	9.6/7.5	83.5/84.2	9.0/8.6
400	7.1/7.0	82.3/82.7	8.2/7.5

was found to remove effectively the large trash particles, sand, dust, kawadi etc Trash removal was observed to decrease with increase in cylinder speed for all cylinders. Trash removal was observed higher for cylinder C_2 compared to C_1 and C_3 (**Fig. 7**). **Fig. 8** shows the effect of cylinder speed on trash removal for cylinder configuration C_2. The trash removal rate was observed to be higher at lower cylinder speed for all the cylinders. The initial trash content for cotton A, cotton B, and cotton C was 2.5 %, 3.0 % and 4.0 % respectively. The machine was found to bring down the trash content by 0.8-1.5 %.for different cottons for cylinder C_2 at 225 rpm. The cleaning efficiency of the developed pre-cleaner was found between 30-40 %. A pictorial view of cleaned cotton obtained from axial flow pre-cleaner is shown in **Fig. 9**.

Fig. 7 Effect of cylinder speed and configuration on trash removal for cotton C

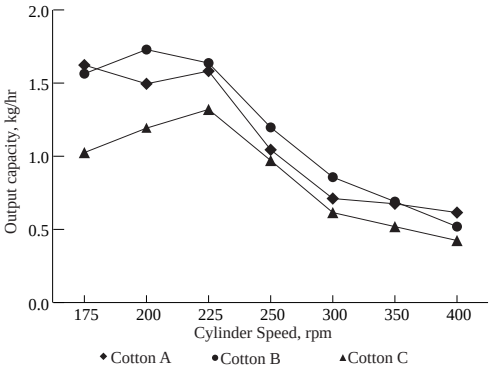
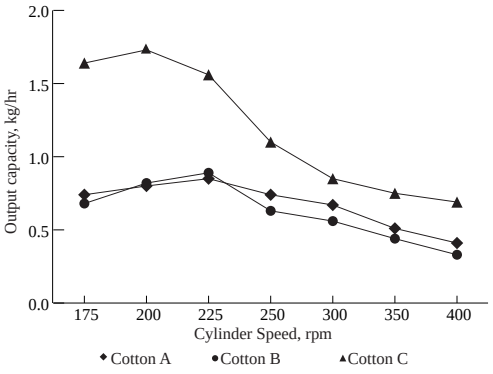


Fig. 8 Effect of cylinder (C_2) speed on trash removal for different cottons



Effect of Axial Flow Pre-Cleaner on Fibre Quality Parameters

Fibre quality parameters such as fibre length, uniformity ratio, micronaire and strength were found unaffected by the use of developed pre-cleaner (**Table 2**). The entanglement of fibres after cleaning was observed at cylinder speeds of 250 rpm and above for all three cylinder configurations. The entanglement of fibres was not observed at cylinder speed below 225 rpm for all three cylinders. The entanglement of fibres results in nep formation which is undesirable. The degree whiteness of the cleaned cotton was found to be improved considerably and yellowness found to be deceased. The short fibre content was found to be lesser in cleaned cotton compared to un-cleaned cotton (**Table. 3**). The overall improvement in visual grade and appearance of the cleaned cotton was noticed.

The cylinder C_2 was observed to be optimum in term of output capacity and trash removal as compared to cylinder C_1 and C_3. Hence based on output capacity, trash removal and fibre quality parameters, the overall performance of the cylinder C_2 at 225 rpm speed was observed to be better compared to other cylinders and other speeds. The optimum output capacity of the machine was found to be 650 kg/h. The machine found to bring down the trash content by about 0.8-1.5 % depending on the initial trash content. The cleaning efficiency of the machine was found to be 30-40 %. Therefore developed machine with cylinder configuration C_2 was recommended with a cylinder speed of 225 rpm.

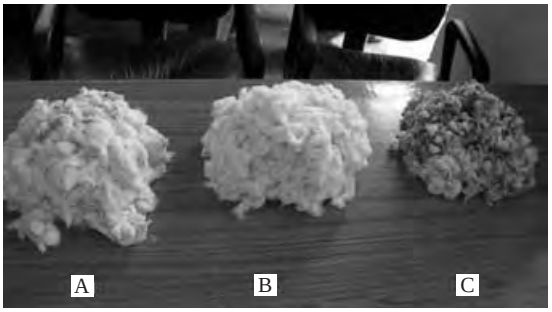
Energy Consumptions

The axial flow pre-cleaner was provided with 2 hp 3 phase motor for driving cylinder and 0.5 hp motor for driving feeder. The energy required for operating the machine was found to be 1kw/h at cylinder speed of 225 rpm.

Cost Economics of Axial Flow Pre-Cleaner

The assessment of techno-economic feasibility was carried out based on the findings and some basic assumptions. The cost of the machine calculated to be Rs. 75,000/-.

Fig. 9 A view of cleaned cotton from accia flow pre-cleaner, A-Un-cleaned cotton, B-Cleaned cotton, C-Trash



Premium on sale of cleaned cotton of Rs. 1000 per tonne was expected. The cost of operation per hour and per tonne was observed to be Rs. 44 and Rs. 67.5 respectively. Additional income to farmer per tonne was found to be Rs. 540. The rate of hiring of machine per tonne of cotton was assumed to be Rs. 100 per tonne. The custom hiring charges was calculated to be about Rs. 109 per hour (**Table 4**).

Conclusions

The single cylinder axial flow cotton pre-cleaner was designed and developed. The overall performance of the machine was found to be satisfactory. It was found that the principle of axial flow could be effectively used for pre-cleaning of cotton. Cylinder configuration (C_2) of 203.2 mm cylinder diameter and spike length of 114.6 mm was found optimum. The optimum cylinder speed was found to be 225 rpm. The capacity of the machine was found to be 650 kg/h. The machine was found to remove effectively the large trash particles, sand, dust, kawadi etc. The machine found to bring down the trash content by about 0.8-1.5 % depending on the initial trash content. The cleaning efficiency of the machine was found to be 30-40 %. The developed machine was not found to affect the fibre qulity parameters such as fibre length, strength and fineness. The degree of whiteness of lint was improved considerably resulting in grade improvement. The cost of operation per hour and per tonne was observed to be Rs.44 and Rs. 67.5 respectively. Additional income to farmer per tonne was found to be Rs. 540. It was observed that axial flow pre-cleaner could be effectively used for on farm cleaning of cotton to enhance farm income.

Table 4 Cost economic of axial flow pre-cleaner

Particulars	Values (Rs.)
Initial cost of machine	75,000/-
Cost of operation per h	44
Cost of operation per tonne of cotton	67.5
Monetary loss per tonne after pre-cleaning due to trash removal	390
Expenditure per tonne after pre-cleaning	460
Premium for cleaned cotton per tonne	1,000
Profit per tonne of cleaned cotton	540
Profit per hour of machine operation	351
Custom hiring of machine	
Rate of hiring of machine per tonne of cotton	100
Rate of hiring per hour	109
Returns per hour to farmer after hiring	242
Earning of machine owner per hour	65
Earning of machine owner per day (8 hours)	520

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Response of an Engine to Biofuel Ethanol Blends



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Abstract

Fuel mixtures like ethanol-diesel blend, diesel-vegetable oil, alcohol-vegetable oil, alcohol-diesel-vegetable oil, ester of vegetable oil-diesel are used as fuel for Compression Ignition (CI) engines. Vegetable and rice bran oil are also being used satisfactorily for partial replacement of the diesel fuel. In the present study, the performance of CI engine fuelled by Rice bran oil methyl ester ethanol blends was evaluated and compared with diesel. Increase in proportion of ethanol in blends decreased the emission of exhaust gases. The engine produced almost similar power on all the fuel blends and its brake thermal efficiency was higher on blended fuel. Though at higher percentage of ethanol, the blends had more brake specific fuel consumption but at the same time the thermal efficiency also increased with increase in ethanol percentage. The experimental results proved that the use of ethanol blended biodiesel in compression ignition engines is a viable alternative to diesel.

Keywords: Biodiesel, blend, rice bran oil, biofuel, transesterification, ethanol

Introduction

Energy is an essential input for economic development and improving the quality of life. At present mankind is facing severe problems of energy crisis; food shortage and environmental pollution due to growing population, expanding urbanization and rapid industrialization. The demand for non-renewable energy sources such as coal, oil, gas etc. is doubling every ten years in most of the developing countries. Biodiesel is an eco-friendly fuel to replace fossil fuels. Also, it is a bio-degradable and non-toxic alternative fuel.

Biodiesel can be produced either with or without catalyst. In the catalyst-assisted biodiesel production, the catalyst used can be a base, acid or enzyme. Alkali-catalyzed transesterification is currently used in the commercial production of biodiesel. With base as catalyst, waste oils rich in free fatty acids (FFAs) and water are difficult to be utilized efficiently since the former result in producing saponified products, while the latter hinders complete conversion of oils (Marchetti *et al*., 2007). Rice bran, a by-product, is obtained from the outer layers of the brown (husked) rice kernel during milling to produce polished rice. Oil content in rice bran is 15-23 % (Houston. 1972). Crude RBO (Rice Bran Oil) has been difficult to refine because of its high FFA content, unsaponifiable matter and dark colour (Houston *et al*., 1972, Bhattacharya *et al*., 1983, Kim *et al*., 1985, Tandy *et al*., 1984, Hartman *et al*., 1976) and any delay between rice milling and bran extraction promotes the hydrolysis of oil and result in the development of high FFA. The rapid increase of FFA in the bran has been recognised as a serious problem for the RBO industry. At present, rice bran is mostly used as animal feed and as boiler fuel (Goffman *et al*., 2003, Shih *et al*., 1999). RBO is not usually common edible oil compared to other traditional cereal or seed sources such as corn, cotton, sunflower, or soybean (Hernandez *et al*., 2000); hence RBO ester was chosen as one of the constituent of the fuel for testing and evaluation.

Ethanol has some detergent properties that reduce build-up of carbon deposits on injectors, which keeps engines running smoothly and fuel injection systems clean for better performance. Less deposition of carbon and therefore reduced abrasive wear in the cylinders was observed due to greater combustion efficiency obtained (Meiring *et al*., 1983). Different fuel mixtures like ethanol-diesel blend, diesel-vegetable oil,

alcohol-vegetable oil, alcohol-diesel-vegetable oil, ester of vegetable oil-diesel etc. have been used as fuel for CI engines. Cetane number of vegetable oil is higher than diesel. Use of vegetable oil and ethanol blend gave satisfactory results (Goering *et al*., 1983). The concept of employing alcohol especially ethanol with ester of vegetable oils as a fuel in engines is new and revolutionary. Since there is no use of diesel, there is 100 % replacement of diesel.

In view of the above, a study was undertaken with the objective of evaluating the performance of a constant speed compression ignition engine fuelled by methyl ester of RBO ethanol blend and comparing it with diesel.

Materials and Methods

A constant speed stationary CI engine (Kirloskar ®, India) was selected for the study. The major specifications of the engine are given in **Table 1**. The experiments were carried out using high speed diesel as reference fuel and different stable blends of rice bran oil methyl ester with ethanol in various proportions as engine fuel. Anhydrous ethanol was used as one of the constituent of blended fuel for the experiment. Rice bran oil methyl ester (RBOME) was used as another constituent of the blended fuel. The ester was prepared by transesterification of the refined rice bran oil procured from the local market. The process parameters used for transesterification of rice bran oil is given in **Table 2** (Singh. 2003). High speed diesel was taken as reference fuel for comparison with the prepared blends of rice bran oil methyl ester and ethanol.

RBOME-ethanol blends were prepared by blending 10 to 90 % ethanol with rice bran oil. But the characteristic fuel properties of the ethanol with more than 60 % in the blend were found unsuitable for fuel testing. The flash point of blends were less than 26 ºC when ethanol percentage increased by 60 %. The details of fuel blends prepared from RBOME and ethanol are given in **Table 3**.

Measurement of Exhaust Gas Temperatures

The exhaust gas temperatures were measured with cromel-alumal thermocouples attached to digital temperature display unit. The thermocouples were inserted at the exhaust gas manifold and in the lubricating oil sump.

Carbon Monoxide (CO) Emission

Initially the engine was run on no load condition and its speed was adjusted to 1,500 ± 10 rpm. The CO contents of exhaust gases emanating from burning of different fuel types at different load conditions were analyzed using a gas liquid chromatograph (Nucon® −5,700). In order to determine the CO content at different load conditions, the exhaust gas samples (20 ml) were injected in to the chromatograph. The amount of CO in the unknown sample was determined by comparing peaks with that of standard one.

Nitric Oxide (NO) Emission

A nitric oxide analyzer, Nucon 500 −NO was used for the estimation of nitric oxide in the exhaust gas. The instrument uses an electrochemical transducer that operates on 230 V AC. It has a range of 0 -1999 ppm. An exhaust gas sample drawn through a pump operating on 230 V AC was fed to the analyzer for the estimation of nitric oxide content in exhaust gas. The exhaust gas sample was directly drawn from exhaust gas manifold using a 3 mm PVC pipe. The measurements were made under all the selected load conditions.

Calculations

After determining the fuel properties of the blends, the performance of the engine was evaluated

Table 1 Specifications of the tested engine

Make	Kirloskar
Model	AV1
Rated Brake Power (kW)	3.73
Rated Speed (rpm)	1,500
Number of Cylinders	1
Bore X Stroke (mm)	80 × 110
Displacement Volume (cc)	552.920
Compression Ratio	16.5 : 1
Standard Injection Timing	27º BTDC
Cooling System	Water Cooled

Table 2 Transesterification process parameters selected to producerice bran oil methyl ester

Process Parameters	Standardized Value
Molar Ratio	5 : 1
Preheating Time, min	30
Preheating Temperature, ºC	60
Reaction Temperature, ºC	60
Reaction Time, h	1
Settling Time	24
NaOH Concentration	0.33 %

Table 3 composition of fuels selected for engine test

Fuel Types		Fuel content (% v/v)	
		Rice bran oil methyl ester	Ethanol
Diesel		--	--
Rice Bran Oil Methyl Ester : Ethanol	100 : 0	100	0
	90 : 10	90	10
	80 : 20	80	20
	70 : 30	70	30
	60 : 40	60	40
	50 : 50	50	50
	40 : 60	40	60

on the eight different fuel types and tested at no load, 20, 40, 60, 80, 100 and 110 % load. The switch over of loads was done through the Eddy Current Dynamometer Controller. For each load condition, the engine was run for at least three minutes after which data were collected.

Brake Horse Power (BHP)

The engine output i.e brake horse power was calculated using the formula 1.

$kW = (N \times T) / C$ .....(1)

where, T = Torque (N-m), N = Engine speed (rpm) and C = Dynamometer constant (9,549.305).

Brake Specific Fuel Consumption (BSFC)

The brake specific fuel consumption which measures how efficiently an engine is using the fuel supplied to produce work was computed using **Eqn. 2**.

$BSFC = (v \times \rho \times 1000 \times 3.6) / (HP \times t)$ .....(2)

Where, BSFC = Brake Specific Fuel Consumption (kg/kW^{-h}), V = Volume of fuel consumed ($2.5 \times 10^{-5} m^3$),= Density of fuel (kg/m^3), HP = Brake power (kW) and

t = Time taken to consume $2.5 \times 10^{-5} m^3$ fuel (s).

Brake Thermal Efficiency

This shows the actual conversion efficiency of the engine i.e. how much useful power we get after burning the fuel. This is calculated by **Eqn. 3**.

$\eta_{th} = K_s / (HV \times BSFC) \times 100$..(3)

where, η_{th} = Brake thermal efficiency, %, K_s = Unit constant, 3600, HV = Heat Value or Gross heat of combustion (kJ/kg) and *BSFC* = Brake Specific Fuel Consumption (kg/kW^{-h}).

Results and Discussion

Engine Performance on Selected Fuels

The engine performance at different loads using diesel, RBOME and rice bran oil methyl ester-ethanol blends mixed in the ratio of 90:10, 80:20, 70:30, 60:40, 50:50 and 40:60 was evaluated in terms of brake power, fuel consumption, brake specific fuel consumption, brake thermal efficiency, exhaust gas and lubricating oil temperatures and emissions of CO, UBHC and NO_x.

Brake power

The brake power and speed of the engine when operating on diesel, rice bran oil methyl ester and the blends of RBOME-Ethanol prepared in 90:10, 80:20, 70:30, 60:40, 50:50 and 40:60 ratio at no load, 20, 40, 60, 80, 100 and 110 % brake load are given in **Table 4**.

It is evident from **Table 4** that at rated load the engine developed brake power of 3.80 kW at 1,529 rpm on diesel. The rated power of the engine as specified by manufacturer is 3.73 kW at 1,500 rpm. At an over load condition i.e. at 110 % load, the engine on diesel developed 4.13 kW, it can be interpreted that with the increase in brake load there was an increase in brake power and decrease in engine speed on all the rice bran oil methyl ester-ethanol blends.

RBOME-Ethanol blends of 70:30 and 40:60 gave slightly higher power than diesel on loads up to 80 % load and 40:60 blends gave higher power than diesel even at 100 % load. The variation in brake power developed by the engine at full load on the tested fuel types reveals that the brake power developed by the engine significantly varied in comparison to diesel.

Brake Specific Fuel Consumption

The brake specific fuel consumption of the engine when developing rated power on diesel was found to be 285 g/kW^{-h} (**Table 5**). The BSFC of rice bran oil methyl ester was found to be 318 g/kW^{-h} while the BSFC of the engine on RBOME-Ethanol mixed in 90:10, 80:20, 70:30, 60:40, 50:50 and 40:60 proportion was computed as 311, 284, 293, 321, 326 and 326 g/kW^{-h} respectively. The highest brake specific fuel consumption at rated load was observed when the engine was operating on blends containing proportion of ethanol as 50 % or more.

It was also noted that at 100, 80 and 60 % brake loads for RBOME-ethanol blends of 80:20 and 70:30, the BSFC was almost the same as for diesel. These loads are important as the engine mostly runs on these loads.

Brake Thermal Efficiency

The brake thermal efficiency of the engine on diesel at rated brake load was observed 26.32 % (**Table**

Table 4 Percentage load and BHP (kW) developed with tested fuels

Load %	Diesel	Rice bran oil methyl ester: ethanol						
		100 : 0	90 : 10	80 : 20	70 : 30	60 : 40	50 : 50	40 : 60
0	-	-	-	-	-	-	-	-
20	0.790	0.779	0.797	0.780	0.811	0.774	0.796	0.821
40	1.572	1.547	1.578	1.546	1.596	1.490	1.554	1.586
60	2.335	2.308	2.293	2.298	2.368	2.269	2.307	2.359
80	3.060	3.028	3.060	3.040	3.142	3.044	3.048	3.125
100	3.802	3.775	3.812	3.758	3.740	3.780	3.720	3.812
110	4.130	4.007	4.064	4.075	3.646	3.840	3.848	4.078

Table 5 Brake specific fuel consumption (g/kW^{-h}) of the engine on tested fuels

Load %	Diesel	Rice bran oil methyl ester: ethanol						
		100 : 0	90 : 10	80 : 20	70 : 30	60 : 40	50 : 50	40 : 60
0	-	-	-	-	-	-	-	-
20	676	874	667	602	594	629	673	683
40	420	507	418	380	381	402	433	436
60	343	403	344	316	322	347	364	360
80	307	355	313	297	303	335	343	340
100	285	318	311	284	293	321	326	326
110	272	317	309	282	301	323	342	346

Table 6 Brake thermal efficiency (%) of the engine on tested fuels

Load %	Diesel	Rice bran oil methyl ester: ethanol						
		100 : 0	90 : 10	80 : 20	70 : 30	60 : 40	50 : 50	40 : 60
0	-	-	-	-	-	-	-	-
20	11.31	9.91	13.24	14.78	15.01	15.58	14.89	16.82
40	17.91	17.06	21.14	23.38	23.37	24.36	23.12	26.31
60	21.91	21.49	25.62	28.09	27.66	28.26	27.50	31.89
80	24.44	24.40	28.15	29.93	29.38	29.24	29.17	33.78
100	26.32	27.23	28.35	31.27	30.40	30.53	30.68	35.20
110	27.58	27.27	28.51	31.45	29.76	30.33	29.24	33.20

6). The comparison of observed brake thermal efficiency indicated that all the blends have higher thermal efficiency than diesel or rice bran oil methyl ester alone. This may be due to higher combustion efficiency caused by the presence of ethanol in the mix as compared to diesel or rice bran methyl ester. The highest brake thermal efficiency (35.2 %) at the rated power as well as other loads was observed on the blend having 40 % rice bran oil methyl ester and 60 % ethanol. This is again due to higher combustion efficiency of ethanol in the mix.

Exhaust Gas Temperature on Tested Fuel Types

The exhaust gas temperature of the engine at full load condition on diesel was found as 750.1 ºC. When the load increased, exhaust gas temperature also increased for all fuel types because of pressure rise in combustion chamber and an increase in fuel injection rate with increase in brake load (**Fig. 1**). The maximum exhaust gas temperature was observed at 110 % brake load and it varied from 410.3 to 881.3 ºC for different fuel types.

It is also observed that the exhaust gas temperature of the engine on rice bran oil methyl ester as well as blends of RBOME-Ethanol was lower than that of diesel under entire range of brake loads (**Fig. 1**). The value of exhaust temperature was nearly 50 % for all the blends of rice bran oil methyl ester-ethanol blends as compared to diesel. This may be due to better utilization of heat released during combustion of fuels and increase in brake thermal efficiency on blended fuels (Gupta 1994).

Lubricating Oil Temperature of the Engine

The lubricating oil temperature of the engine at full load condition on diesel was found as 70 ºC and on blends of RBOME-Ethanol prepared in the ratio of 100:0, 90:10, 80:20, 70:30, 60:40, 50:50 and 40:60 was found as 63.0, 62.0, 61.0, 63.0,

Fig. 1 Exhaust gas temperature of engine at different brake loads on tested fuels

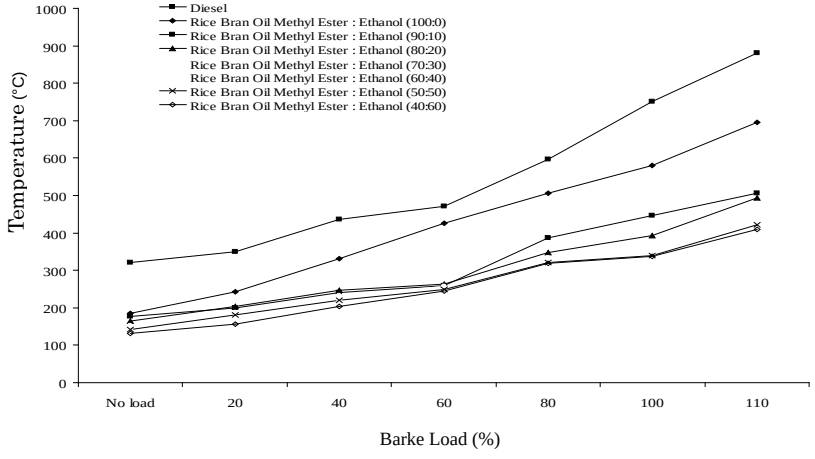


Fig. 2 Lubricating oil temperature of engine at different brake loads on tested fuels

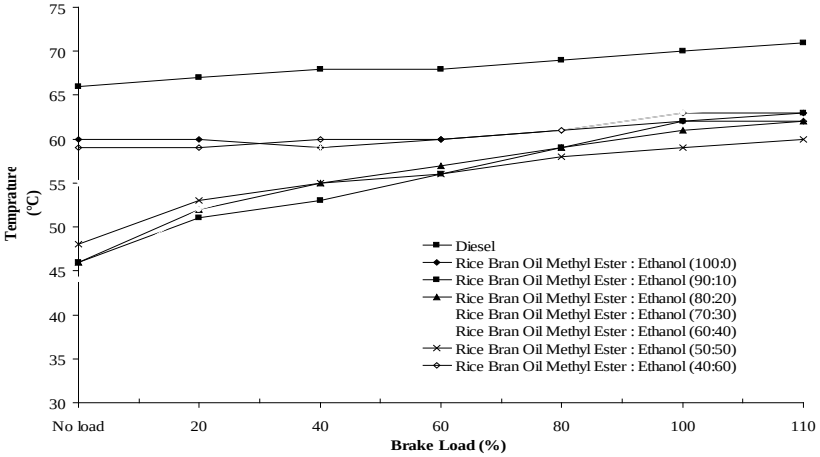


Fig. 3 Carbon mono-oxide emission of engine at different brake loads on tested fuels

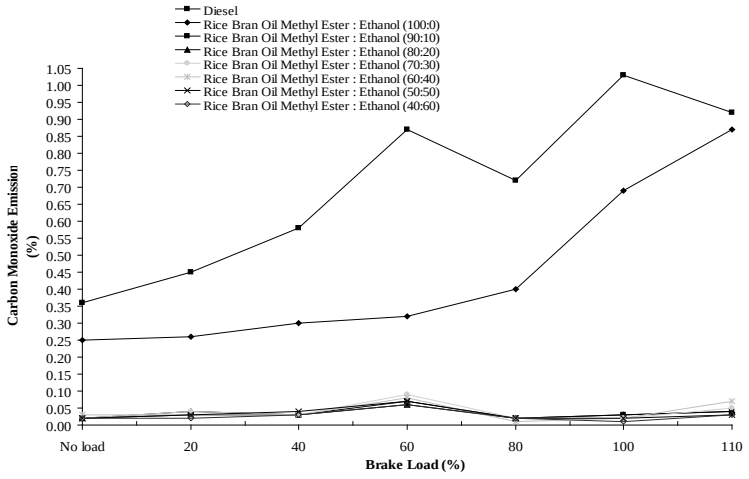
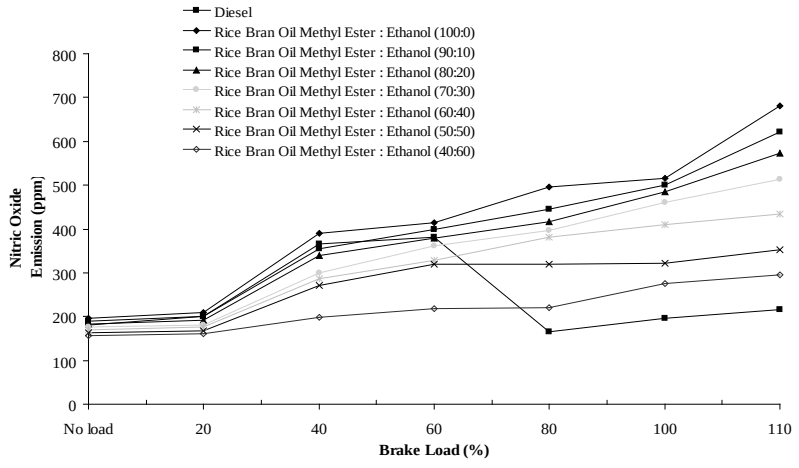


Fig. 4 Nitric oxide emission of engine at different brake loads on tested fuels



64.0, 59.0, and 62 ºC respectively (**Fig. 2**). It is evident from the figure that the lubricating oil temperature of the engine decreased for all fuel types as compared to that of diesel. This may be due to higher combustion efficiency of fuel blends with ethanol. It also indicated that engine will run cooler when operated with fuel blends as compared to diesel.

Effect of Fuel Types on Exhaust Emissions from the Engine

Carbon Monoxide Emission

The carbon monoxide emission from the engine on diesel and the selected blends at different loads is shown in **Fig. 3**. It was observed that the emission of CO from the engine on diesel varied in the range of 0.36 to 1.03 % between no load and 110 % brake load. Emission of CO for the same load conditions was found in the range of 0.25 to 0.87, 0.02 to 0.07, 0.02 to 0.06, 0.02 to 0.05, 0.03 to 0.08, 0.02 to 0.07 and 0.02 to 0.06 % on the blends of RBOME-Ethanol 100:0, 90:10, 80:20, 70:30, 60:40, 50:50 and 40:60 proportions respectively.

It was also observed that for entire range of brake loads almost all the blends of RBOME-Ethanol showed much lower emission of CO in comparison with diesel fuel. The reduction in carbon monoxide emission of blended fuels may be due to presence of additional oxygen molecules in blended fuels.

Nitric oxide emission

The emission of nitric oxide from the engine on diesel fuel was found to be in the range of 165.6 to 381.2 ppm at various brake loads (**Fig. 4**). The observed values of nitric oxide emission at rated load condition when engine operating on RBOME-Ethanol blends in 100:0, 90:10, 80:20, 70:30, 60:40, 50:50 and 40:60 proportions was found to be 516.5, 500.2, 485.6, 460.3, 409.2, 322.5 and 276.0 ppm respectively.

It is evident from the results that emission of NO increased with increasing in brake load when the

engine was operating on different blends of RBOME-Ethanol. It was further noted that from no load to 60 % load conditions all the fuel blends were found to follow similar trends as that of diesel. However, for higher loads of 80, 100 and 110 %, the nitric oxide emission with diesel decreased with increase in load whereas it increased for all the blends of fuel with increase in load. But as the ratio of ethanol increased in the blend, the NO emission went down; this might be due to decreased volume of the rice bran oil ester.

The NOx emission was more in all the cases of blends of rice bran oil and its ester which might be due to presence of phosphatidyle choline lipids in all the vegetable oils. Cholines consist of primary, secondary and tertiary nitrogen which changes into NOx at higher temperature in the presence of oxygen as reported by Houston (1987). The increase in NOx emission may be due to the oxygen present in biodiesel, which is added to fuel rich zones, resulting in the oxidation of nitrogen (Serdari *et al*., 2000, Nabi *et al*., 2006).

Conclusions and Recommendations

The engine developed power almost similar to diesel when rice bran oil methyl ester-ethanol blends mixed in 100:0, 90:10, 80:20, 70:30, 60:40, 50:50 and 40:60 proportions were used at every selected brake load conditions. The BSFC of the rice bran oil methyl ester-ethanol blends mixed in 80:20 and 70:30 ratios was found close to diesel. The emissions of CO and UBHC from the engine on the selected fuels were found to be either close or lower with respect to diesel. These blended fuels which are devoid of diesel work comfortably with the traditional engines of farmers. But there is still need for long duration engine test to watch the effect over engine life.

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Development of an Image Analysis System for Sowing Machine Laboratory Tests

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Abstract

Aim of this research is to develop an experimental apparatus to measure distances between seeds for precision sowing machines and to count number of seeds in a determined area for bulk drillers on a conveyor band by using image analyses techniques. System consists of a conveyor band, two cameras, a light, a computer, which includes an image acquisition board, an input board and a software to realise the desired measures using some image processing algorithms. Wheat, sunflower, onion, and sugar beet seeds were used in this research. The results showed that there is no statistically significant differences between measurement of the image analyses system and human.

Keywords: Seed distribution model; Artificial vision; Machine test

Introduction

Seed spacing depends mostly on the types of planting machines, whether a row crop planter or a grain drill (Bernacki *et al*., 1972). Non-uniformity of seed spacing is generally related to the method of seed delivery to furrow and the planter travel speed (Fornstrom and Miller, 1989). The most common method for testing planters in the lab is the Grease belt system (Kelly *et al*., 1993). Opto-electronic sensors have been developed for measuring the spacing distribution of seeds, instead of the adhesive belts. (Lan *et al*., 1998; Kocher *et al*., 1998; Muller *et al*., 1994). In a recent work, kinetic image processing was applied to measure seed distribution (Hu *et al*., 2000). Different spaced seeds were prepared by using wheat, corn, tomato, vetch, carrot and sugar beet seeds. The images of these samples were displayed on the computer screen and analyzed by using image processing software (Dursun and Dursun, 2000). A test bed was equipped with a 35 mm camera used to measure the moving trail and velocity of seeds falling from different heights, their impact with the surface of the earth, and their total displacement. In addition, a photoelectric sensor system capable of quickly measuring seed intervals was developed (Shresta *et al*., 2004). An optical system, based on a line scan camera and image processing algorithms was developed for on-line measurement of seeds interval distribution. The optical resolution of the system enables to measure the spacing distribution of small seeds (Kasthi and Brikman, 2000). A high-resolution optical system for evaluation of performance parameters of pneumatic planters was developed (Alchanatis *et al*., 2002). A dynamic test of a precision seeder at stepless speed (0.5 m/s^{-3} m/s) was developed, then a image processing and analysis technique was used to examine the precision of the seeders and the accuracy of the procedure

(Wei *et al*., 2003). A high-speed camera system for evaluating seed spacing uniformity and velocity of fall of seeds was described and the camera system worked well in obtaining the seed spacing and velocity of fall of seeds (Karayel *et al*., 2006). An opto-electronic sensor system was tested by comparing seed spacing measurements obtained from the opto-electronic system with measurements of the same seed spacing obtained from a grease belt test stand (Lan *et al*., 1999). Mathematical and statistical fundamentals of drilling technique are presented in the "Test Guide of Cereal and Cotton Sowing machines" (Anonymus, 1999).

The objective of this research is to develop an experimental apparatus to measure distances between seeds for precision planting machines and to count number of seed in a determined area for bulk drillers by using image analyses techniques. Developed experimental system will help to collect data on a conveyor band for evaluating of sowing machines and to determine seed distributions in the laboratory.

Material and Methods

Experimental Apparatus

The apparatus consists of a conveyor band, two cameras (model Sony XC_HR50), a light source, a Leutron Picture capture card and a special software (**Fig. 1**).

Length of the conveyor band is 2,000 mm and a width 200 mm. The speed can be adjusted between 0 m/s and 2.5 m/s. and measured by encoder fitted to the electrical engine axle. The speed of the electrical engine is adjusted by changing electric frequency.

The planting machine was located at the top of the bench. Wheel of the planting machine was driven by a hydraulic motor. An adhesive material was used on the bench for seeds to stick. Fallen seeds from planting machine were located on the bench. The camera took pictures with a frequency of 30Hz. From these images and the position of the seeds on the bench obtained from the encoder, the software developed realizes the measurement of the distances between seeds and the counting of the seeds in determined areas. Artificial vision system, a Sony XC-HR50 camera was used to capture the images. These cameras were small but fast enough to capture fast moving objects. A backlighting was used in order to obtain satisfying images to be computed by an image-processing algorithm. The background was white so the seeds can be detected easily on the bench. Visual Basic and Halcon 7.1 were used to develop this application. A ring light was used around the camera to have a uniform lighting.

Seeds

Wheat, sunflower, onion and sugar beet seeds were used in the tests.

Planting Machines

Planting machine with toothed roller (**Fig. 2**) and a pneumatic precision planting machine (**Fig. 3**). were used in this research.

Fig. 1 Experimental test system for determination of seed distribution

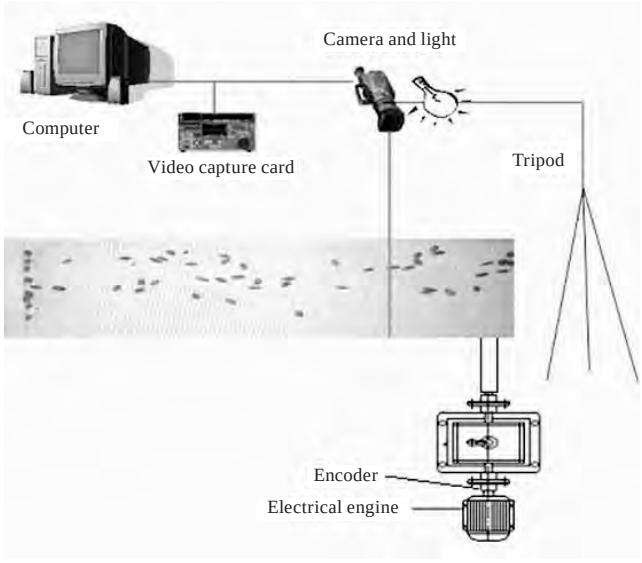


Fig. 2 General view of test system

Fig. 3 Laboratory tests of precision planting machine

Seed detection

The images were acquired in colour. Then an algorithm was applied to transform these ones in grey level. A work had been realized, using many images, to research the parameters which characterized, as better as possible, the kind of seeds considered. These parameters were mean, minimal and maximal surface of a seed, convexity, minimal and maximal grey level of a seed. The user could also define other parameters, for example the perimeter or other geometric properties.

To localize the seeds in an acquired image in real time, a local threshold operation was applied in the different windows of the image at first time, to detect the seeds using the grey level parameters characterized the seeds. Then convexity parameter was used and applied some morphological operations like erosion and dilatation to remove the noise. A label was applied to identify the different seeds. Thus the seeds could be isolated or grouped. So in order to separate the seeds, the surface parameters were used. The surface of one group of pixels was divided by the mean surface of one seed to obtain the number of seeds presents in the group. The picture given below presents the detection of different sunflower seeds or group of seeds in an image using the developed software (**Fig. 4**).

Fig. 4 Seed detection

Measurement of the distance between seeds

The computer was connected to the conveyor band by Advantech IO Card. Using the information given by the encoder, exact position of each image on the conveyor was estimated at real time. Thus the distance between two consecutive seeds or the space between them considering the direction of the bench by helping the computer program can be measured. Sunflower seeds on the bench can be seen in **Fig. 5**.

Counting of Seeds Considering Determined Areas

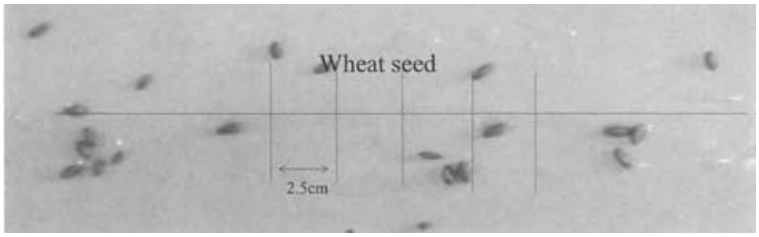
The aim of this application was to count the number of seeds in different areas and to evaluate the quality of planting machines for wheat. Researchers are generally interested in the counting of seeds in a width of 2.5 cm. on the band; however, the width of the area depends on planting rate (**Fig. 6**).

Checking the System

Developed experimental test system was checked by comparing results with manual measurements. Differences between two results were calculated and compared sta-

Fig. 5 Sunflower seeds on the bench and hand measurement

Fig. 6 Wheat seeds on the bench



tistically by using Chi-square test. Descriptive statistics such as maximum, minimum, mean, standard deviation were calculated (Duzgunes *et al*., 1983).

Results

The image processing algorithms were developed and realized in Visual Basic environment. This application provides Graphical User Interface (GUI) for both the camera that observes falling seeds and the camera that observes the seeds on conveyor. The application had many features such as multi region progress, recording data, real time video sequence player and several run time modes. It could process two cameras at the same time. However, it was not recommended to run these two threads together since it cannot share the CPU (central Process Unit) at some points and slows down the performance.

One important application was that the software included a Video Sequence Generator (VCR). The camera would take photograph up to 25 fps but a real application may go beyond that. To cover up this deficiency VCR could be used. Before running VCR the user specifies if it will be run or not. Then the application would perform its usual task. However, this time the VCR objects are put in an array list running. When VCR is run it reads the array and supplies an interface where the user can play with the images. The user can see the images in the recorded sequence, and the number of seeds that has been calculated. If the user detects seeds that has not been counted or that has been counted more than they are, the user can change this seed count by specifying the number of extra or missing seeds. This data is recorded to be viewed later so that the software can be upgraded. Also the VCR class was developed in a reusable way. The user also has the access to change image-processing settings. This is actually done by letting the user change the parameters that seed counting algorithm uses. Same algorithm can be used under a variety of lighting and environment conditions. This supplies flexibility to the software. In multi region processing the user can have many regions of interests for different purposes of run. For example, the region (or domain) that is drawn for the counting seeds on the conveyor may not be the same with the one that was drawn for measuring the seeds on the conveyor. System check results were given in **Tables 1**, **3, 5** and **7**. Differences between the developed image analyses and person are given in **Tables, 2, 4, 6**, and **8**.

If results evaluated for wheat seed distribution;

a: Difference of maximum values of the seed number image analyses system and person is 2

b: There is no differences between minimum values

Table 1 Seed number of wheat for checking the test systems

	Measured by camera (number)	Measured manually (number)	Differences
Total measurement number	34	34	
Mean	7.79	8.41	0.62
Max.	15	17	2.00
Min.	4	4	0.00
Standard deviation	3.30	3.29	0.01

Table 2 Error of the image analyses system for wheat

Measurement error* (Number of seed)	Number of the measurement	Percentage (%)
0	17	50 %
1	11	32 %
2	6	18 %

Chi-square (calculated) = 1.0 (not significant)

Chi-square (from table) = 47.40 (df = 67, P = 0.05)

* Difference between two measurement methods

Table 3 Distances between sunflower seeds for checking the test systems

	Measured by camera (mm)	Measured manually (mm)	Difference (mm)
Measurement number	58.00	58.00	0.00
Mean (mm)	86.28	87.41	1.13
Maximum (mm)	143.33	118.00	25.33
Minimum (mm)	31.19	30.00	1.19
Standard deviation (mm)	29.10	29.50	0.40

Table 4 Error of the image analyses system for

Measurement Error* (mm)	Number of the measurement	Percentage (%)
0	19	32.75
1-2	7	12.06
2-3	11	18.90
3-4	8	13.79

Chi-square (calculated) = 1.0 (not significant)

Chi-square (from table) = 75.62 (Degree of Freedom = 67, P = 0.05)

* Difference between two measurement methods

Table 5 Distances between onion seeds

	Measured by camera (mm)	Measured manually (mm)	Differences (mm)
Measurement number	67	67	
Mean (mm)	62.19	61.73	− 0.46
Maximum (mm)	100.52	100.00	4.16
Minimum (mm)	24.81	25.00	0.19
Standard deviation (mm)	17.04	16.79	0.25

Table 6 Error of the image analyses system for onion

Measurement error* (mm)	Number of the measurement	Percentage (%)
0	38	56.71
1-2	16	23.88
2-3	7	7.00
3-4	4	4.00
≥ 5	2	2.00
Chi-square (calculated) = 1.0 (not significant)		
Chi-square (from table) = 87.11 (Degree of Freedom = 67, P = 0.05)		

* Difference between two measurement methods

Table 7 Distances between sugar beet

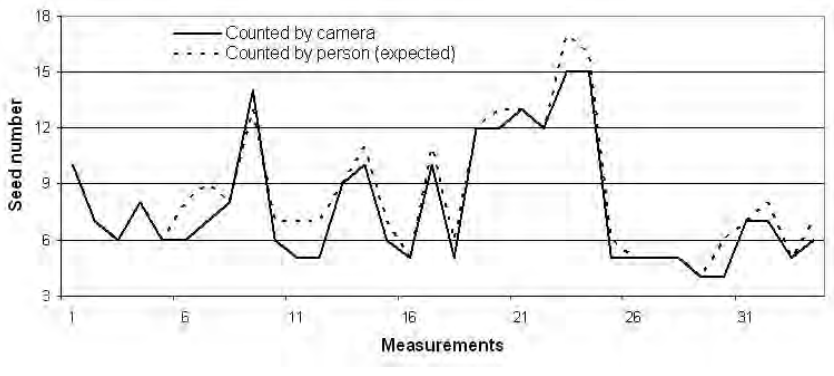
	Measured by camera (mm)	Measured manually (mm)	Differences (mm)
Measurement number	62	62	
Mean (mm)	68.09	68.27	0.18
Maximum (mm)	109.57	110.00	7.09
Minimum (mm)	32.20	30.00	− 5.51
Standard deviation (mm)	18.29	18.23	2.30

Table 8 Error of the image analyses system for sugar beet

Measurement error* (mm)	Number of the measurement	Percentage (%)
0	25	40.32
1-2	11	17.74
2-3	16	25.81
3-4	4	6.45
≥ 5	2	3.23
Chi-square (calculated) = 1.0 (not significant)		
Chi-square (from table) = 80.23 (Degree of Freedom= 67, P = 0.05)		

* Difference between two measurement methods

Fig. 7 Differences between counted seeds by camera and by person



c: Standard deviations is too close to each other as 3.30 and 3.29

d: According to the chi-square test, differences between camera and person measurements is not important (**Fig. 7**).

If results evaluated for sunflower:

a: Differences between maximum values of the camera and person are 25.33 mm.

b: Differences between minimum values are 1.19 mm.

c: Standard deviations are 29.10 mm and 29.50 mm, for the camera and person, respectively.

d: According to the chi-square test; differences between camera and person measurement is not important (**Fig. 8**).

If results evaluated for onion seed measurements:

a: Differences between maximum values are only 4.16 mm.

b: Differences between minimum values are 0.19 mm.

c: Standard deviations are 17.04 mm and 16.79 mm, for the camera and person, respectively.

d: According to the chi-square test; differences between camera and person measurement is not important (**Fig. 9)**.

If results evaluated for sugar beet;

a: Difference between maximum values of the camera and person is only 7.09 mm.

b: Differences between minimum values are 5.51mm.

c: Standard deviations are too close to each other and its value is 17.04 mm and 16.79 mm, for the camera and person, respectively.

d: According to the chi-square test; differences between camera and person measurement is not important (**Fig. 10**).

Conclusions

The results of the counting of the seed numbers of the wheat showed that there was no difference between the image analyses system

and person measurements for total number of the maximum and the minimum of the measurements. Standard deviations of the measurements of two systems were too close to each other. Differences between measurements of both systems were not significant statistically.

Distances between seeds of sunflower, onion, and sugar beet indicated that there were not any significant differences between total number of measurements for camera and person. There were differences between two measurement systems. Because the image analyses system calculated distances between seeds from centre to centre. Person cannot determine exact centre of seeds when measuring the distances between seeds. Consequently, there are always differences between measurement of image analyses system and by hand in the laboratory tests.

Researchers can get more data by using this image analyses system. Performance tests of planting machines are generally carried out for 15 meters in 3 replications in the conventional grease belt test. If the developed test system works for 5 minutes as an example, data may be collected for 300 meters, approximately. The developed image analyses system can be used instead of sticky belt system to carry out laboratory tests of sowing machines.

Fig. 8 Differences of test method measurements for sunflower

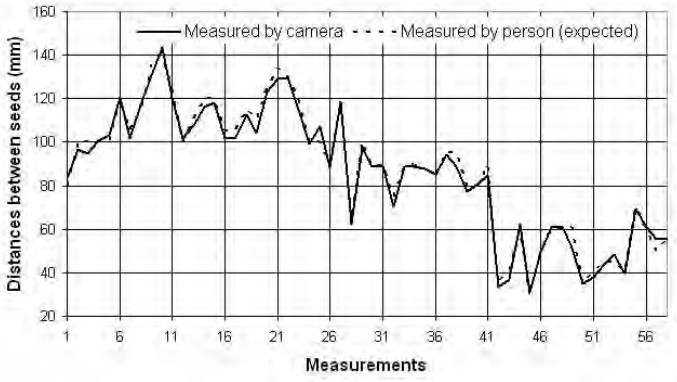


Fig. 9 Differences of test methods measurements for onion

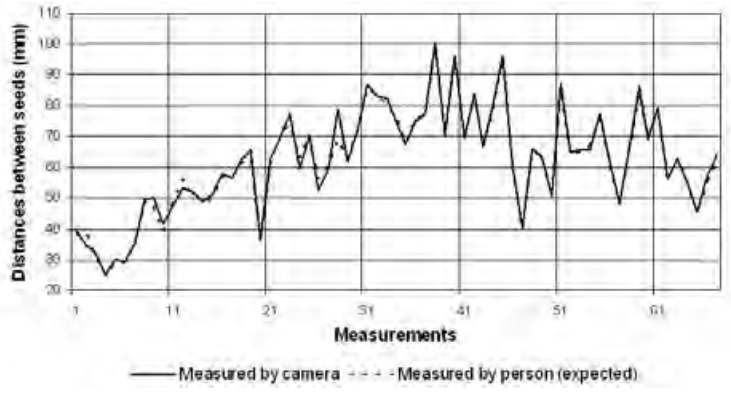
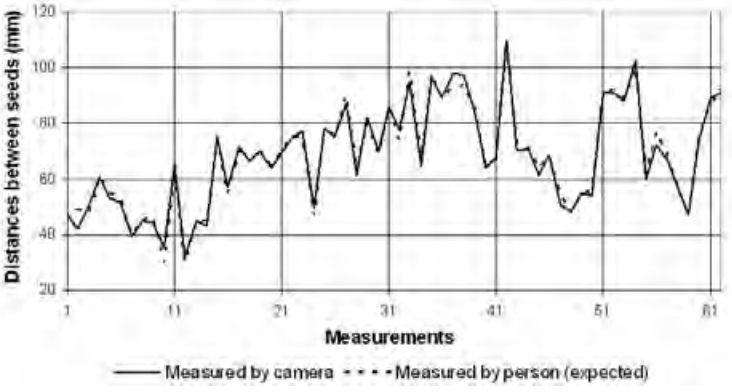


Fig. 10 Differences of test methods measurements for sugar beet



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ABSTRACTS

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

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Effect of Soil Surface Condition and Depth of Ploughing on Energy Requirements of Two Tillage Implements

Mohamed Hassan Dahab, Department of Agricultural Engineering, Faculty of Agriculture, University of Khartoum Shambat, SUDAN; and Ahmed Osman Ahmed ElAttaya, same.

An experiment was carried out on a vertisol clay soil at Gezira University farm, Wad Medani, Sudan, to investigate the effects of soil surface condition and depth of ploughing on energy requirements of two tillage implements, disc plough and disc harrow. The two soil conditions were loose and firm surfaces with three ploughing depth 10 cm, 15 cm and 20 cm.

The results showed that, the highest unit draft, fuel consumption and energy requirements were given by the disc plough in the firm soil surface as, 12.68 kN, 15.31 /ha and 159.6 MJ/ha respectively. As the depth of ploughing was increased from 10 cm to 20 cm, the values of all measured parameters increased for both soil conditions and implements. The differences between the effects of treatments on unit draft, fuel consumption and energy requirements were highly significant at 1 % level. The interactive effects of treatments were found insignificant. The multiple correlation analysis showed that soil surface condition and depth ploughing jointly accounted for 88.4 %, 97.1 % and 88.4 % of variability in unit draft, fuel consumption and energy requirements of disc plough respectively. While for disc harrow they accounted for 88.4 % of unit draft, 85.8 % of fuel consumption and 88.2 % of energy requirements variability.

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Use of Queueing Theory to Organization of the Complex Rice Harvest-Transport on the Agroindustrial Rice Complex "Los Palacios"

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Abstract

The present research was carried out on the Agroindustrial Rice Complex "Los Palacios", on Pinar del Rio province. The investigation had as main goal to study of the means stop probabilities, on the base of stochastic process, considering economical features that appear during the work of the complex rice harvest-transport with the harvester machine New Holland TC-57 and the joint tractor New Holland TS-6020 with trailers RA-6, looking for its rational organization. The Queuing Theory was used for the solution of this problem taking the economical criteria of its optimization the minimum added expenses in one hour by harvester machines and means of transport stops in service. It was also determined the quantity means of transport for a harvester brigade under probabilistic basis.

Keywords: rice, probabilities, mechanization.

Introduction

For the organization of the harvest-transport brigade of the rice, it is important to consider technical and economic aspects based on the minimum expenses for unit of time and/or unit of grain harvested and transported. The factors considered that make noticeable influence include the harvester machine productivity, the means of transport capacity, the distance of transportation, the vials type and conditions, the waiting time to the charge of grain on the field and the discharge on the Reception Center (Betancourt and Bullaín, 2007).

The Queueing Theory was studied by (A. Kaufmann, 1981) and others authors (Cooper, 1981; Gross and Harris, 1985; Kashyahp and Chandry, 1988; Medhi, 1991; Walfrand, 1988; Wolff, 1989) making possible the analysis of waiting phenomenon that is related with the stochastic process through mathematical models. The process makes possible to annex the probabilities; besides facilitating to make decisions that give the possibility to improve the process organization and the systems rationality on the basis of costs reduction.

There are few developed research about the Queueing Theory used in the agricultural process. The present research is about the technological harvest-transport process of the rice that analyses every component conforming the complex parameters that made an influence in the efficiency of this process. The organization of the process harvest-transport considered the economic criteria of the minimum added expenses for the harvester machine and the means of transport stops during one hour.

Materials and Methods

Theoretical fundaments to the organization of the rice harvest-transport process.

During the mechanized harvest flow several kinds of machines were used, such as: harvester machines, means of transport and Grain Reception Center. The condition of continuity of productive flow is the equality between productivities of every mechanized link for a brigade.

$$n_1 W_1 = n_2 W_2 = \ldots n_i W_i \quad (1)$$

Where:

n_i: Quantity of joints for a link i determined;

W_i: productivity of the joint in the productive link i.

During the harvest-transport process the pendulum route is used (distance travelled with charge until the Reception Center and distance travelled empty till the field) (Iglesias *et al*., 2012).

Determination of the Harvest-Transport Means Organization Using the Queueing Theory

The effective work of the harvest-transport complex depends on the transport service organization; therefore the rational determination of this means presents some difficulties during the productive process.

In production condition, in the moment of harvester machine was filled with grain and then arrival to the field by means of transport do not correspond. For this reason the duration of the turn time depends on the travel speed for the times used in the Reception Center, and for the harvester machine location on the field and in the path outside the field. Other causes that have an influence in the harvester machine filling with grain are: the relief, the productive yield, the grain humidity during the working day, etc. All the factors previously mentioned can produce the unproductive stop of the harvester machine and means of transport. (Iglesias *et al*., 2011; Iglesias, 2006).

Economically, it is convenient to have minimum relation between the quantity of harvester machine and means of transport (Pérez and Iglesias, 1992). This criteria was achieved by the following expression:

$$S = C_{pc} \times \lambda \times t_{esp} + C_t \times n, \text{ peso/h} \quad \text{.....(2)}$$

Where:

C_{pc}: Losses per one hour of harvester machine stop waiting the means of transport to serve, peso;

λ: Mean quantity of harvester machine filled of grain (Demand of service in one hour);

t_w: Waiting mean time of every demand, h;

C_t: Cost per hour in the maintenance of the means of transport, peso/h;

n: Quantity of means of transport to give services to a harvester machines group.

In the queueing system, the stationery single flow of Poisson is used which is free of consequences. This means that in equal time, the demand of a service for two or more is few probable, for this, it is important to consider the following hypothesis:

1st: The probability P_c (t) does not depend of the time interval and do not have dependence of the initial time;

2nd: Two events never occur at the same time (the probability that two events happen together is very small);

3rd: If it is considered a very small time interval Δt, selected in whichever instant, the probability is equal to $\lambda \Delta t$; the quantity λ is called mean rate of enters or demand average of service in a unit of time.

The magnitude φ can be any value (coefficient of system charge). A steady regime exists when $\varphi < n$, in contrary case $\varphi \geq n$ the system can not satisfy the demand and the queue grow indefinitely.

Results and Discussion

Determination of the Harvest-Transport Means Organization Using the Queueing Theory

For the determination of the rational quantity of transport means was taken a harvest-transport brigade conformed by three harvester machines New Holland TC-57 and a transport link conformed by tractors New Holland TS-6020 everyone with two trailers RA-6. The rice field had a mean yield of 3.7 t/ha, and the transportation distance was of 13 km on pavement and 5 km on land from to the harvest field until the Reception Center.

The results obtained were the following:

The productivity of the harvester machine in explotation time to an agricultural yield of 3.7 t/ha was 3.03 t/h.

The cycle time was of 4.02 h, this value is considered elevated, the main cause of this value was the vials conditions.

Using the expression 4 was possible determining the quantity of means of transport without considering the probabilities being this 4.56 means, but for the real conditions four means were considered, taking this quantity of means as comparison base for two, three, four, five and six means of transport, to determine the probabilisti-

Table 1 Result of the probabilistical character to organize the harvest-transport brigade

Indicators	Quantity of means of transport				
	2	3	4	5	6
Capacity of the service channel, μ	0.49	0.74	0.99	1.24	1.49
Coefficient of system charge, φ	4.53	2.23	2.24	1.79	1.48
Probability that two enters (harvester machines) demand a service at the same time, P_c (t)	0.059	0.059	0.059	0.059	0.059
Probability that all service channels (transport) stop, P_o	-	0.073	0.097	0.17	0.22
Probability that all enters (harvester machine) are exactly busy, P_c	-	0.47	0.63	0.82	0.73
Probability that exist a queue in the harvester machine service, P_{queue}	-	0.53	0.37	**0.18**	0.27

cal and economical characters.

The mean time of the harvester machine to fill its capacity for this yield was 0.45 h, So in one hour the channel (λ) can satisfy 2.22 joints of transport.

The **Table 1** shows the probabilistical character of the harvest-transport; when the quantities of means of transport change, showing that with five means of transport the probability that exist a queue in the harvester machine service is lower.

Table 2 shows the determination of rational variant to organize the harvest-transport brigade on economical base, showing that with five means of transport the value of the addition of losses per stops is lower.

Conclusions

1. This research validates the aplication of Queueing Theory for the rational organization of the harvest-transport complex, considering probabilistical and economic aspects.
2. The probabilistical character is directly proportional to the addition of losses per stops because of the variant of five transport joints was the minimum cost per stops and the minimum probability that exists in a queue in the harvester machine service.
3. The rational quantity of transport joints is five with a cost of 71.46 peso/h, that in comparison with the actual cost of 75.84 peso/h, thus obtaining an income of 43.8 peso per working turn.

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Table 2 Result of the determination of rational variant to organize the harvest-transport brigade

Indicators	Quantity of means of transport				
	2	3	4	5	6
Quantity of means of harvester machine in waiting to be served, ms	-	3.93	2.54	2.30	2.25
Waiting mean time in queue of the harvester machines (tesp), h	-	1.77	1.14	1.03	1.01
Losses per harvester machine stops, peso/h	-	104.6	67.36	60.86	59.68
Losses per means of transport stops, peso/h	-	6.36	8.48	10.60	12.72
Addition of losses per stops, peso/h	-	110.96	75.84	**71.46**	72.4

Studies on Pre-Cooling of Tomato

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Abstract

Precooling involves rapid removal of field heat from freshly harvested fruits and vegetables prior to loading for transport to market before storage. Low temperatures slow down the metabolic processes such as respiration and transpiration, and delay the development of post-harvest diseases by inhibiting host ripening. In the present study an evaporative cooler was developed. The performance of the same was tested for various cooling pad material, airflow and water flow rates. Among the pad material tested, plywood scratches performed well. Tomatoes pre-cooled in the evaporative cooler and stored in plywood box insulated container had a shelf life of two days more than the tomatoes kept without pre-cooling.

Introduction

One of the most important factor affecting the post-harvest life and quality of horticulture crop is temperature of the produce. Quality losses after harvest occur as a result of physiological and biological processes, the rate of which is influenced primarily by product temperature. As the maintenance of market quality is of vital importance to the success of the horticulture industry, it is necessary not only to cool the product, but to cool it as quickly as possible after harvest (Brosnan and Sun, 2001). Low temperature handling and storage are the most important physical method of post-harvest management.

Precooling is defined as a process in which the fruit must be cooled to required temperature, which will inhibit growth of decay producing micro-organisms, restrict enzymatic and respiratory activities, inhibit water loss and reduces ethylene production in the product (Hardenburg *et al*., 1990).

Precooling involves rapid removal of field heat from freshly harvested fruits and vegetables prior to loading for transport to markets before storage. Within precooling, numerous techniques exist for removal of field heat and increasing shelf life of fruits. Hydro-cooling, forced air cooling, vacuum cooling, top icing, evaporative cooling and room cooling are the methods in commercial use at present (Joshi, 2004).

Many fruits and vegetables benefit from prompt cooling immediately after harvest. Low temperatures slow down metabolic processes such as respiration and transpiration and delay the development of post-harvest diseases by inhibiting host ripening, by prolonging diseases resistance associated with in maturity, and by directly inhibiting the pathogen at temperatures unfavorable to its development. Precooling is the first step in the handling of many fruits and vegetables (Tabil and Sokahansanj, 2001).

Moretti *et al*. (2009) reported that rapid cooling methods such as forced-air cooling, hydro-cooling and vacuum cooling demand considerable amounts of energy. Therefore, it is anticipated that under warmer climatic conditions, fruit and vegetable crops will be harvested with higher pulp temperatures, which will demand more energy for proper cooling and raise product prices.

Mencarelli *et al*. (2005) pointed out the reason for adopting a precooling technique is to avoid water loss and to shut down the temperature rapidly to match the storage of shipping thermo hygrometric conditions immediately. Thus, precooling techniques are technologies used to reduce rapidly the temperature of horticultural commodities, removing field heat and decreasing rate of respiration. Techniques used are room cooling, forced air cooling, hydro- cooling, vacuum cooling and ice cooling. Another technique, especially valid when primary sources like capital and electric power are not available, is evaporative cooling.

Jha and Chopra, (2006) studied the effect of various types of bricks and cooler pads o absorption and evaporation of water from their surfaces at different temperature and relative humidity to select the suitable one. They found that clay and sand lime bricks and partal pads were found to be most effective and economical for use in evaporative cooled storage structure.

Jha and Kudos (2006) studied the

physical properties of various pad materials like partal, safeda and rootpad for maximizing cooling in evaporative cooled store and reported that partal had maximum porosity and rootpad had the minimum. It was also reported that the surface evaporation of water from the cooling pad increased with increase in ambient temperature and decrease in relative humidity irrespective of pad material and thickness.

Jha (2008) studied the performance of the evaporative cooled storage structure in terms of temperature drop and weight loss of stored product and reported that a temperature of 20 ºC and relative humidity of 78 % was achieved in summer.

Hence the present study is formulated with the objective of developing an evaporative type pre-cooler and to conduct pre-cooling studies.

Methods and Materials

An experimental cooler was developed which consisted of an evaporating pad, an axial flow fan, water supply system and a cool chamber and is shown in **Fig. 1**. The wall of the cooling chamber was made of mild steel sheet of 20 gauge thickness and insulated with 25 mm thermocole packing. The area where the axial flow fan is placed was insulated with 6 mm acrylic sheet. The fruits were placed in crates inside the cooling chamber.

Evaporative Pads

Charcoal, coirpith, paddystraw and plywood scratches pads were used in this experiment and were either filled or inserted inside a box of size 570 × 570 × 25 mm made of wire mesh. The pad materials were selected based on their availability, durability, wettability and non-degradability.

Water Supply System

Water was fed from a tank of 70 L capacity placed below the evaporative pad assembly outlet as shown in **Fig. 1**. A 0.25 HP water pump (UP National Manufactures Ltd, India) was provided to lift the water collected in the tank to the water distribution system, placed on the top of evaporative pad assembly. It consists of five 16 mm PVC pipes of 250 mm length, each placed parallel to each other and perforated with 4 mm holes at a pitch of 110 mm. The holes of one pipe were offset by 5 mm with the next row of pipe. A gate valve was provided along with the water pump to regulate the flow of water. By the above described water supply system continuous flow of water was maintained over the evaporative pads.

Air Supply System

An exhaust fan of 450 mm sweep running at 230 V, 50 Hz was provided at the back of the evaporating pad, to draw the air through the wet pad. A dimmer starter of 8 Amp was attached to the fan for operating the fan at different speeds to get different airflow rates. The fan was operated at the desired speeds that produced airflow rates of 0.55, 0.65 and 0.75 m^3/s.

Evaporative Pad Assembly

A rectangular box was used for filling materials that provided the evaporative surface for cooling. It was also provided for a fixed thickness of evaporative surface. This consisted of a rectangular box of dimension 570 × 570 × 25 mm made of wire mesh with square holes of 50 × 50 mm. The box was closed on its sides and bottom with the same wire mesh and the top was kept open. The base of the box was provided with a close net wire mesh, to avoid passage of evaporative pad surface materials into the tank. The box was filled with four readily available materials for use as evaporating surfaces in the experiment.

Charcoal

Charcoal obtained from the local market was manually screened for uniformity in size between 20 mm and 250 mm. The screened charcoal was thoroughly washed and filled into the wire mesh box.

Coir pith

Coir pith obtained from local coir

Fig. 1 Evaporative Cooler

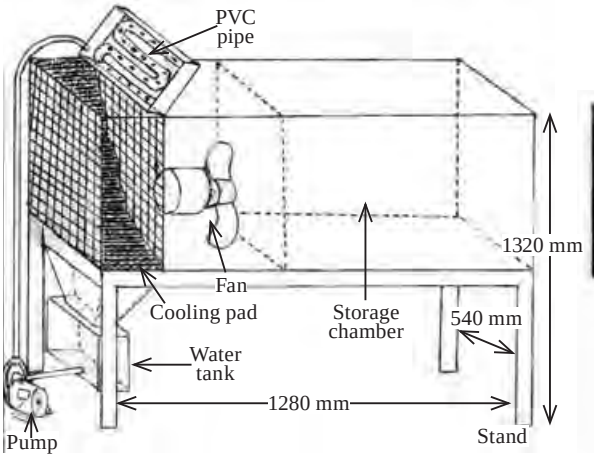
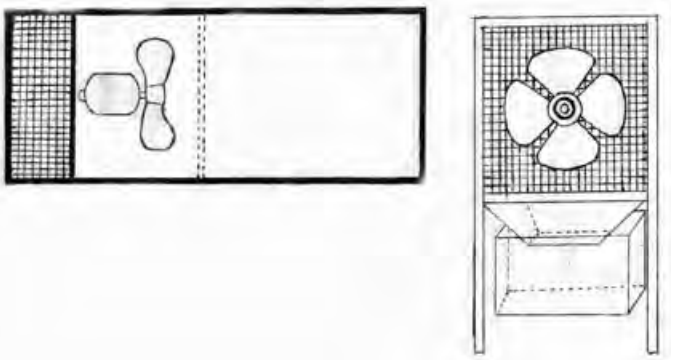


Fig. 2 Top view and Side view



industry was collected, sieved to remove fine particles and fibres were used as pad material.

Paddy straw

Paddy straw of good quality was selected and used for the study.

Plywood Scratches pad

Plywood scratches pad of thickness 5 cm that is commercially available was purchased and was filled inside the wire mesh box to a thickness of 25 cm. The pads totally covered the whole area of the box to obtain maximum cooling efficiency.

Cooling Chamber

The cooling chamber of size 1000 × 570 × 570 mm was provided next to the chamber containing exhaust fan, which acts as essential area in the cooler for the storage of fruits and vegetables. The cooling chamber was insulated on its sides and top with 25 mm of thermocole packing. The chamber containing exhaust fan was insulated with 6 mm thickness acrylic sheet. The side of the chamber was covered with a door of 710 × 530 mm and was insulated with thermocole. Four vents were provided at the exit of the cooling chamber for the exhaust air to escape. The air that is escaping through these vents could be regulated by closing or opening the vents as desired.

Performance Evaluation of Evaporative Cooler

The developed cooler was evaluated for the cooling efficiency and humidifying efficiency. The experiments on the cooler was carried out with four evaporative pad surfaces for three varying air flow rates at three different water flow rates. The experiments were replicated three times.

Measurement of Air Velocity and Fan Speed

Air flow rate was calculated by multiplying the velocity with the cross-sectional area of the cooling chamber. The speed of the fan was measured using a hand held digital tachometer (Systems, India Model: HTM 590).

Measurement of Temperature and Relative Humidity

A digital type temperature and relative humidity (RH) measuring instrument (Equinox, India Model: DT615) was used to measure the dry bulb temperature and relative humidity inside and outside the cooler. The wet bulb temperature was obtained from the psychrometric chart.

Cooling Efficiency

Cooling efficiency of the different evaporative pads was calculated using the formula given by Dzivama *et al.* (1999).

$$\text{Cooling efficiency } (\eta_c) = [(T_{db} - T_{exit}) / (T_{db} - T_{wb})] \times 100$$

where,

T_{db}: dry bulb temperature of the air entering the pad, ºC

T_{wb}: wet bulb temperature of the air entering the pad, ºC

T_{exit}: dry bulb temperature of air exiting the pad, ºC

Humidifying Efficiency

The Humidifying efficiency of the cooler was calculated by the following relationship (Dzivama *et al.* 1999).

$$\text{Humidifying efficiency } (\eta_h) = [(H_c - H_a) / (H_{sat} - H_a)] \times 100$$

where,

H_a: relative humidity of ambient air entering the pad, percent

H_c: relative humidity of air exiting the pad, percent

H_s: relative humidity of saturated air, 100 percent.

Storage of Fruits

Tomato fruits were harvested from farmer's field and were sorted. Bruised and injured fruits were removed. Fruits of 15 kg were placed in plastic crates, vented on sides and bottom. Cold and humidified air from the evaporative pad was passed to the chamber through the exhaust fan and was discharged through the vents at the exit of the cooler. Fruits were pre-cooled to a temperature of 26 ºC and stored in insulated containers. In addition, the storage studies were carried without pre-cooling and ambient conditions for comparison and as control respectively.

Various physicio-chemical characteristics estimated during storage were, weight loss, firmness, colour total soluble solids and acidity Fruit samples were taken from the above mentioned three types of storages as per the requirement and the physio-chemical analysis were carried out.

Physiological Loss In Weight (Plw)

From the initial and final weight of fruits physiological weight loss was calculated.

Firmness

Firmness of the fruit was found by using TA-XT2 texture analyzer (Stable Micro Systems Ltd, NewDelhi.) using 2 mm cylindrical probe.

Colour

Colour change in fruit during storage period was measured using colorimeter (Hunter Color Lab, Model no. 45/0).

Total Soluble Solids (TSS)

TSS was measured using ATAGO (Japan) pocket refractometer (0 - 93 %) and the total soluble solids were measured as percentage Brix.

pH

Acidity of the fruit was measured using digital type PH meter (model Equinax pH-101).

Statistical Analysis

The mean values of three replications of cooling efficiency and humidifying efficiency for the different treatments were compared adopting Randomized Block Design(RBD) using AGRIS statistical software

Results and Discussion

Effect of Evaporative Pad, Water

Table 1 Effect of airflow, water and cooling pad on the cooling efficiency

Cooling pad (P)	Air flow rate 1			Mean	Air flow rate 2			Mean	Air flow rate 3			Mean	Grand Mean
	W_1	W_2	W_3		W_1	W_2	W_3		W_1	W_2	W_3		
P_1	42.00c	44.53c	30.67c	39.07	43.67c	45.03c	32.10c	39.58	45.00c	46.40c	33.70c	40.16	39.60
P_2	31.07d	32.17d	30.00c	31.08	32.00d	32.53d	30.60d	31.35	33.00d	34.00d	31.70d	31.77	31.40
P_3	51.67b	52.60b	38.90b	47.72	53.03	56.27b	40.67b	48.69	55.00b	57.27b	43.07b	49.54	48.65
P_4	53.47a	56.70a	41.90a	50.69	55.53a	58.90a	43.47a	51.52	57.10a	61.17a	45.13a	52.33	**51.51**
Mean	44.55	**46.50**	35.37	42.14	46.06	**48.18**	36.71	42.79	47.53	**49.71**	38.40	**43.50**	42.81

				A × C × W
CD (5 %)				1.241

Flow Rate and Air Flow Rate on Cooling Efficiency

The effect of airflow rate on cooling efficiency of various pad material for water flow of 5 lit/min is given in **Fig. 3**. It could be observed that when air flow rate increased cooling efficiency also increased.

The interactive effect of evaporative pad, water flow rate and airflow rate is presented in **Table 1**. From the table it could be observed that the maximum cooling efficiency of 61.17 % was obtained for plywood scratches pad material at an air flow rate of 0.75 m^3/sec and water flow rate of 5 L/min. The lowest cooling efficiency of 30 % was obtained for coirpith pad material at an water flow rate of 7 L/min and airflow rate of 0.55 m^3/sec.

In general, it was observed that cooling efficiency increased with increase in air flow rate. But at water flow rate of 7 L/min it decreased compared to 3 and 5 L/min. This could be due to saturation of air at high water flow rate. Similar trend was noticed for all the pad material. From the table it was observed that a water flow rate of 5 L/min was found to be optimum. Considering air flow rate 0.75 m^3/sec was found to give maximum cooling efficiency.

From the statistical analysis of data, it was found that the interaction effect was significant at 5 % level.

Among the pad materials plywood scratches performed well and coir pith produced low cooling efficiency.

Effect of Pad Material, Air Flow Rate and Water Flow Rate on Humidifying Efficiency

The effect of pad material air flow rate and water flow rate on humidifying efficiency is depicted in **Fig. 4**. It was found that an increasing trend was noticed for humidifying efficiency with respect to air flow rate and water flow rate.

Among the various pad materials tested ply wood scratches performed well and the performance of charcoal pad was found to be poor.

The interaction effect of pad material, airflow and water flow on humidifying efficiency is given in **Table 2**. It could be observed that maximum humidifying efficiency of 67.7 % was obtained at water flow rate of 7 L/min and airflow rate of 0.75 m^3/sec for plywood scratches pad. The lowest humidifying efficiency of 60.5 % was obtained for charcoal pad for air flow rate of 0.55 m^3/sec and water flow rate of 3 L/min. In general it was found that humidifying efficiency increased with increase in air flow rate and water flow rate. From the statistical analysis of the data it was found that for the cellulose pad material for airflow of 0.75 m^3/sec the humidifying efficiency was on par for all the three water flow rate tested.

Among the pad materials tested plywood scratches pad performed well.

Selection of Pad Material, Water Flow and Air Flow Rate

From the statistical analysis it was found that the maximum cooling and humidifying efficiency were ob-

Fig. 3 Effect of air flow rate on cooling efficiency for various pad material (water flow rate 5 L/min.)

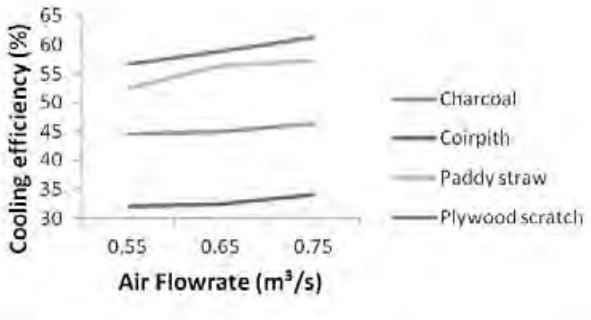


Fig. 4 Effect of air flow rate on humidifying efficiency for various pad material (water flow rate 5 L/min.)

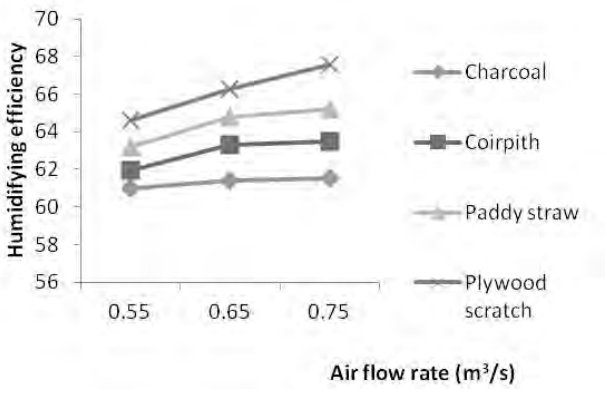


Table 2 Effect of airflow, water and cooling pad on the humidifying efficiency

Cooling pad (P)	Air flow rate 1			Mean	Air flow rate 2			Mean	Air flow rate 3			Mean	Grand Mean
	W_1	W_2	W_3		W_1	W_2	W_3		W_1	W_2	W_3		
P_1	60.93b	61.00c	61.2c	61.23	60.57c	61.40c	61.87c	61.28	60.80c	61.50d	62.00b	61.43	61.31
P_2	61.57ab	61.93bc	62.17bc	61.89	61.43c	63.33b	63.87b	62.88	62.67b	63.47c	63.60b	63.25	62.67
P_3	62.53ab	63.20ab	63.40b	63.04	63.23b	64.77ab	65.47ab	64.49	64.07b	65.23b	66.43a	65.24	64.26
P_4	63.13a	64.60a	65.33a	**64.35**	65.40a	66.27a	66.40a	**66.02**	66.67a	67.57a	67.70a	**67.31**	**65.89**
Mean	62.04	62.81	**63.04**	62.63	62.66	63.94	**64.40**	63.67	63.55	64.44	**64.93**	**64.31**	63.53

				A × C × W
CD (5 %)				1.66

Table 3 Effect of pre cooling on Physico-chemical qualities and self life of tomato stored in Saw dust insulated plywood box

Treatment	PLW (%)	Firmness (g/s)	TSS (Brix)	pH	L	a	b	Storage days
Pre cooled to 26c and stored	5.76	386.9	4.31	4.09	42.51	32.42	30.2	9
Delayed and stored	6.16	350.35	4.44	4.21	42.04	30.95	29.51	8
Control	6.54	343.05	4.70	4.71	39.95	30.65	27.51	7
CD (5 %)	0.111	1.019	0.0682	0.066	0.286	0.240	0.336	

tained with plywood scratches pad. The cooling efficiency was found to be maximum at air flow of 0.75 m^3/sec and water flow rate of 5 L/min. At this condition humidifying efficiency was also found to be high.

Hence plywood scratches pad with air flow of 0.75 m^3/sec and water flow of 5 L/min was selected for the study.

Storage Studies

The results of the storage studies conducted using plywood box insulated with sawdust is given in Table 3. From the table it can be observed that pre-cooled fruits had a shelf life of 9 days while the fruits kept without pre-cooling had a shelf life of 8 days. The extension in shelf life could be due to temperature maintenance of pre-cooled fruits in plywood box. It was also found from the table that the quality of the pre-cooled fruits was better compared to the fruits kept in ambient condition.

Conclusion

An evaporative cooler was developed that was used for conducting pre-cooling studies. Among the pad materials tested plywood scratches performed well. From the storage studies conducted, it was found that pre-cooled fruits had more shelf life and maintained quality compared to the fruits without pre-cooling.

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Effect of Coatings on Physical and Engineering Properties of Carrot (*Daucus carota L.*) Seeds in relation to the Planter Design

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Abstract

The biometric properties of seeds play an important role in designing seed metering device. Physical and engineering properties of carrot seed both uncoated S_1 and coated with biogas slurry S_2 and Thirame S3 were evaluated in the laboratory. The average length and breadth of the uncoated, slurry coated and Thirame coated seed were 2.90 ± 0.58 and 0.96 ± 0.2 mm; 3.01 ± 0.45 and 1.02 ± 0.1 mm; 2.77 ± 0.69 and 1.40 ± 0.42 mm, respectively. Biogas slurry coating enhanced the length and breadth, mean diameter of seed with 5 % level of significance. Roundness and sphericity of uncoated, slurry coated and Thirame coated seed were 48.82 ± 0.33 and 34.57 ± 0.34; 30.75 ± 0.27 % and 34.4 ± 0.41; 44.12 ± 0.42 % and 33.3 ± 0.21 %, respectively. Mean diameter was maximum for Thirame coated seed S_3 (1.33 ± 0.26mm) followed by slurry coated seed S_2 (1.23 ± 0.18 mm), and uncoated seed S_1 (1.17 ± 0.11 mm), respectively. Thousand seed weight, W 1,000 of S_1, S_2 and S_3 was 1.63 ± 0.13 g, 2.15 ± 0.6 g and 3.77 ± 0.50 g, respectively. Percent increment in 1,000 seed weight of S_2 was 24.03 due to biogas slurry coating and the W 1,000 of S_3 was highest, which was 56.37 percent higher than the uncoated seed S_1. Angle of repose and static coefficient of friction for mild steel surface were 35.3 ± 14.1º and 0.73 ± 0.05; 36.13 ± 10.8º and 0.74 ± 0.03; 36.46 ± 13.1º and 0.78 ± 0.1 for uncoated seed S_1, slurry coated seed S_2 and Thirame coated seed S_3, respectively.

Key words: Angle of repose, coefficient of static friction, metering device, carrot, Thirame

Introduction

Carrot (*Daucus carota L.*) commonly known as gajarin India is grown all over the world in spring, summer and autumn in temperate countries and during winter in tropical and subtropical climate. India is one of the largest producer of carrots in the world with an annual production of 3.5 million tons from 0.14 million ha (NHB 2009-10) (Bijay Kumar *et al*., 2010) with productivity of 14.26 tonnes per hectare. It is an important source of carotene, widely recommended by physicians for a number of medicinal purposes contains Vitamin A, B and C as well as calcium pectate. Its pectin fibre is beneficial in lowering cholesterol level of the body. Black carrot is used for the preparation of a beverage called kanji considered to be a good appetizer. Bahadur Singh *et al*. (2006) reported that carrots are also beneficial for the heart, blood circulation, eye sight, skin and lungs. Carrot increases the quantity of urine and helps the elimination of uric acid. Eating carrots is also good for allergies, anaemia, rheumatism, and it serves as a tonic for

the nervous system. It is specially valued in different parts of country for its delicious dish Gajar Halwa. It has been reported that carrot leaves are eaten in many countries, its tops can be used as a good source for extraction of leaf proteins. Moreover, carrot tops are used as fodder and also for preparation of poultry feed.

It is recommended to sow the carrot seeds over the raised bed. The biometric properties of seeds are very important in designing seed metering device (Jayan and Kumar, 2004) and components of planter. Davies (2009) reported that, some physical properties of groundnut, namely geometric mean diameter, bulk density, true density, seed weight and seed volume influenced the performance of planter. Therefore, the present study was undertaken to investigate the physical and engineering properties such as size, shape, 1,000 seed weight, W 1,000, bulk density, angle of repose and coefficient of static friction of carrot seeds under different treatments. The treatments involved were, uncoated seed S_1, biogas slurry coated seed S_2 and Thirame coated seed S3, respectively.

Notations

A_c	area of smallest circumscribing circle, mm^2	W 1,000	1,000 seed weight, g
A_p	projected area, mm^2	μ	coefficient of static friction
l	length of seed, mm	ø	angle of repose
b	breadth of seed, mm	R_p	roundness, %
t	thickness of seed, mm	D_s	sphericity, %
d	geometric mean diameter, mm	ρ_b	bulk density, g cm^{-3}
S_1	Uncoated seed	S_2	biogas slurry coated seed
S_3	Thirame coated seed		

Materials and Methods

In the present study, the carrot seed of 'Nantes' variety was used. It is a European cultivar, which can be grown in the plains of India for root production, but not for seed production. The uncoated carrot seeds were small in size. It was difficult to meter the seed by any metering system. To enhance the size and to improve free flow of carrot seeds in metering unit, they were coated with concentrated biogas slurry and Thirame fungicide. Biogas slurry is a digested by-product of livestock manure that contains a lot of nitrogen, phosphorus, and other macro- and micronutrients. Farmers of India have a good opportunity to use biogas slurry as a nitrogen fertilizer and coating material, because 4.47 million biogas plants has been established in the country (MNRE 2011-12). Therefore, the biogas slurry was selected for coating, as it is easily available to farmers.

Physical and engineering properties for three levels of carrot seeds were measured. To determine the size of carrot seed, 20 seeds from each treatment selected randomly and their physical dimensions (length, breadth and thickness) were measured by digital varnier calliper to an accuracy of ± 0.01mm.The geometric mean diameter of seed, d, is computed using the equation.

$$d=(l \times b \times t)^{1/3} \quad \text{.....(1)}$$

Where; l is the length of seed in mm; b is the breadth of seed in mm; and t is the thickness of seed in mm. The shape of the seed was expressed by its roundness and sphericity (Mohsenin, 1986). The percent roundness of seed Rp was calculated as follows:

$$R_p = (A_p / A_c) \times 100 \quad \text{.....(2)}$$

Where: Ap is the projected area of seed in mm^2; and Ac is the smallest circumscribing circle in mm^2.

The sphericity is a measure of shape character compared to a sphere of the same volume. Assuming that volume of the solid is equal to the volume of tri-axial ellipsoid with intercepts a, b, c and that the diameter of circumscribed sphere is longest intercept of the ellipsoid, the degree of sphericity was calculated as follows (Mohsenin, 1986):

$$D_S = (\sqrt[3]{l \times b \times t}) / l \quad \text{.....(3)}$$

Where:

D_S: Degree of sphericity in %

b: Longest intercept normal to l, mm

l: Longest intercept, mm,

t: Longest intercept normal to l and b, mm

The procedure was repeated for 20 seeds selected randomly. The experiment was repeated for different treatments of carrot seed.

The average bulk density of carrot seed for different seed treatments was investigated using gravimetric method (Singh andGoswami, 1996). The cylinder was filled with seeds without compaction and then weight was taken. The bulk density was calculated as follows:

$$\rho b = W/V \quad \text{.....(4)}$$

Where: ρb is the bulk density in g cm^{-3}; W is the Weight of seed in g; V is the Volume of cylinder in cm^3.

The 1,000 seed weight, W 1,000 was measured by means of an electronic balance with a minimum least count of 0.01 g. The dynamic angle of repose was measured with an apparatus consisting of a funnel with a throat opening mounted on a stand. A circular plate, with four centring arms, was mounted in the funnel above the adjustable throat. The funnel was filled with seed by keeping its adjustable throat closed. The throat was fully opened to allow the free flow of seed over and around the plate mounted in the funnel. At the end, a heap-cone of seed was made on the plate. The angle of cone was calculated using the base and height dimensions of the seed cone.

The coefficient of static friction for two different surfaces namely, mild steel and aluminium were measured for carrot seed using inclined

plane method (Jayan and Kumar, 2004). The material was kept on the adjustable tilting plate and the slope was gradually increased. The angle at which the seed just started to move downward was recorded. The coefficient of static friction μ was determined from the tangent of the angle of slope ø. All the experiments were replicated ten times and repeated for different seed treatments. The 't' test was used to analyse the data statistically using SPSS package.

Results and Discussion

Seed Dimensions

The mean length of the carrot seeds S_1, S_2 and S_3 were 2.65 mm, 3.01mm and 2.77 mm, respectively. Breadth of the seeds S_1, S_2 and S_3 were 0.96, 1.02 and 1.40 mm, respectively. Both length and breadth of seeds S_2 and S_3 were observed to increase with coating (**Fig. 1**). Biogas slurry coating improved the length and breadth of carrot seeds with the 5 percent level of significance. Mean thickness and Geometric mean diameter of three carrot seeds S_1, S_2 and S_3 were 0.59 mm and1.17 mm; 0.61 mm and 1.23 mm ; and 0.63 mm and 1.33 mm; respectively. There was no increment in the thickness of carrot seeds and significant increment was observed in mean diameter of coated seeds S_2 and S_3 in comparison of the uncoated seed S_1. It was observed that due to biogas slurry coating the mean length, breadth and mean diameter of seed S_2 increased by 12.64 %, 5.88 % and 5.12 %, respectively.

Shape of the Seed

The shape of the seed in terms of roundness and sphericity was studied. There was no increment in roundness and sphericity of carrot seeds due to coating, however, a marginal variation was noticed (**Fig. 2**). The roundness of carrot seeds were 31.82 %, 30.75 % and 33.34 % for three treatments of carrot seeds viz. S_1, S_2 and S_3, respectively. The sphericity of carrot seeds S_1, S_2 and S_3 were 34.57 %, 34.4 % and 44.14 %, respectively. The carrot seeds even after coating were far away from roundness and gave clue to avoid round shape of cells over seed plate periphery. The coefficients of variation for roundness and sphericity of three forms of seeds were less than 10 percent. The roundness and sphericity observed in case of carrot seed in different treatments were such that shape of the carrot seed could be assumed to be non- spherical. Therefore, the shape of the cell for seed plates could be triangular, semi-circular, slant type and L-shaped with characteristic dimensions greater than or equal to the length, breadth and mean diameter of seed.

Bulk Density and True Density of Seed

Average bulk density of carrot seeds S_1, S_2 and S_3 were 0.34, 0.28 and 0.47 g cm^{-3}, whereas true density 0.49, 0.49, and 0.68 g cm^{-3}, respectively (**Fig. 3**). The bulk density and true density were highest for biogas slurry coated seed S_3 as 0.47 g cm^{-3} and 0.68 g cm^{-3}, respectively.

The increase in the bulk density of seeds S_2 and S_3 was due to higher thousand seed weights W 1,000 than volume of seeds. The true density of seed S_3 increased from 0.49 to 0.68 g cm^{-3} as it was coated with Thirame fungicide; this was due to the increase in single seed volume.

Thousand Seed Weight

The value of thousand seed weight increased from 1.63 g to 2.15 g due to the slurry coating. Increment in thousand seed weight of S_2 was 24.03 % as compared to the seed S_1 (**Fig. 3**). Thousand seed weight, W 1,000 of S_1, S_2 and S_3 was 1.63 ± 0.13 g, 2.15 ± 0.6 g and 3.77 ± 0.50 g, respectively. The maximum seed weight of 3.77 g was observed in case of Thirame coated seed S_3 which was 56.37 % higher than the uncoated seed S_1.

Angle of Repose and Coefficient of Static Friction

Average value of angle of repose for the carrot seeds S_1, S_2 and S_3 were 35.35º, 36.13º and 36.46º, respectively. The maximum value of

Fig. 1 Length, breadth and thickness of carrot seed for treatments S_1, S_2 and S_3

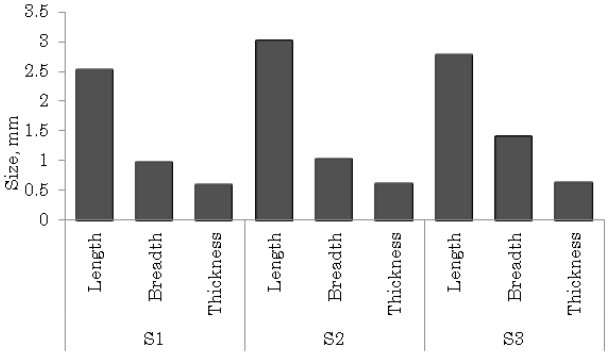
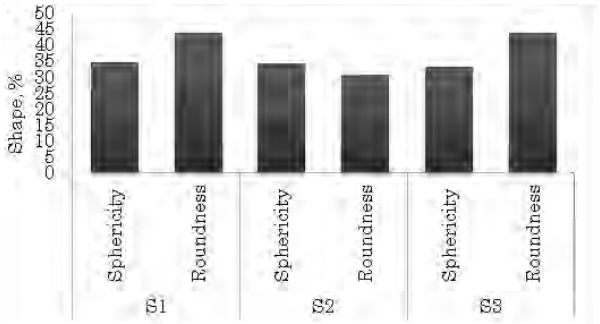


Fig 2 Sphericity and roundness of carrot seed for treatments S_1, S_2 and S_3



angle of repose was 38° for seed S_3. The coefficients of variation in all cases were less than 10 percent. The mean values of coefficient of friction of seed for mild steel surface were 0.73, 0.73 and 0.78 for uncoated seeds S_1, Biogas slurry coated seed S_2 and Thirame coated seed S_3, respectively. Similarly, for the aluminium surface, mean values of coefficient of static friction were 0.69, 0.68 and 0.68 for S_1, S_2 and S_3, respectively. The maximum value for coefficient of static friction was recorded for mild steel surface for seed S_3. At higher seed weight, the seed became rougher which diminished sliding ability. T-test indicated no significant difference in the means of angle of repose and coefficient of static friction for three forms of carrot seed.

Table 1 Physical and engineering properties of carrot seeds under different seed treatments

Properties	Seed Treatments		
	Uncoated (S_1)	Slurry coated (S_2)	Thirame coated (S_3)
Length(mm)	2.63 ± 0.58	3.01 ± 0.45	2.77 ± 0.69
Breadth (mm)	0.96 ± 0.2	1.02 ± 0.1	1.40 ± 0.42
Thickness (mm)	0.59 ± 0.05	0.61 ± 0.06	0.63 ± 0.06
GMD (mm)	1.17 ± 0.11	1.23 ± 0.18	1.33 ± 0.26
Sphericity (%)	34.57 ± 0.34	34.4 ± 0.41	33.3 ± 0.21
Roundness (%)	48.82 ± 0.33	30.75 ± 0.27	44.12 ± 0.42
Bulk density (g/cc)	0.34 ± 0.01	0.28 ± 0.03	0.47 ± 0.05
Seed weight (g)	1.63 ± 0.13	2.15 ± 0.6	3.77 ± 0.50
Angle of repose(deg)	35.3 ± 14.1	36.13 ± 10.8	36.46 ± 13.1
Coefficient of friction	0.73 ± 0.05	0.74 ± 0.03	0.78 ± 0.1

Conclusions

Seed coating with concentrated slurry resulted in increased seed length, geometric mean diameter and seed weight. The percentage increment in the linear dimensions of seeds viz., length, breadth, and mean diameter was significant as indicated by t-test. The linear dimensions of the Thirame coated seed were also higher in comparison to the both uncoated and slurry coated seeds. The roundness and sphericity observed for different forms of carrot seed were very less due to its irregularity in shape and hence the shape of the carrot seed assumed to be other than spherical.

The Increment of Physical Properties was to the Extent as Follows:

1. The increment in average length of slurry coated seed (S_2) was 12.64 % with the 5 percent level of significance.
2. The increment in geometric mean diameter of biogas slurry coated seed (S_2) was 5 percent. The higher mean diameter was 1.33 mm for treatment Thirame coated seed (S_3).
3. The increment in thousand seed weight of slurry coated seed (S_2) was about 24.03 percent and that of the Thirame coated seed (S_3) was 56.37 percent higher than the uncoated seed (S_1).
4. The average values of roundness of carrot seed were to the tune of 31.05 %, 30.75 % and 33.34 % for three treatments viz. uncoated seed, biogas slurry coated seed and Thirame coated, respectively which confirmed that carrot seeds even after coating were far away from roundness. This gave clue to avoid round shape of cells over plate periphery.
5. Highest value of angle of repose was 38° for Thirame coated seeds S_3, because of the roughness and higher seed weight of seed.
6. The highest value for coefficient of static friction was 0.78 for mild steel surface at seed S_3, this was due to the higher thousand seed weight of Thirame, which directly enhanced the frictional properties of surface.

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Fig 3 Bulk density, true density and weight of seed for treatments S_1, S_2 and S_3

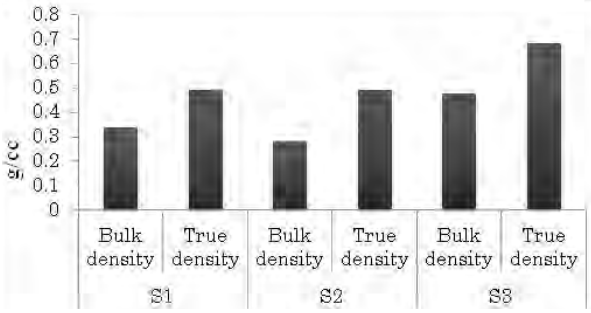
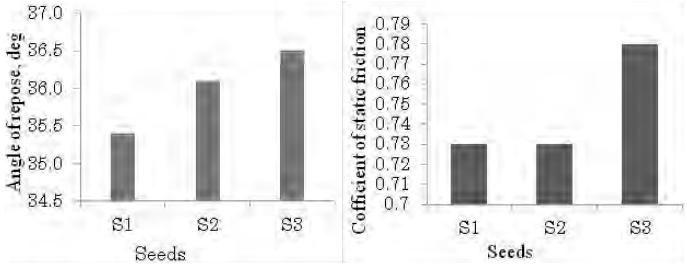


Fig 4 Frictional properties for different seed treatments



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Mechanization Status of Saffron Production in Jammu & Kashmir State of India

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Abstract

In India the State of Jammu and Kashmir holds a unique distinction of producing Saffron (Crocus Sativus L.) with a history of about 2,500 years. Saffron in Kashmir region is grown on an area of about 3,200 ha and average land holding of saffron farmers is 0.56 ha. Saffron cultivation is not highly mechanized in this day and age, although it requires high labour input during the most important growing phases. There are limited machines capable of totally mechanizing the crop production of saffron and research till now has always tried to adapt existing machinery to reach individual phase of its cultivation, rather than design specific machines. Most of the field operations for saffron production in the state are carried out manually using indigenous tools mainly Rampa or Khurpi for Weeding, Tangru-small and large for hoeing and Spade (Zoni) for movement of soil and opening drains.

Introduction

Saffron, the world's most expensive spice, is derived from the stigmas of the saffron crocus (Crocus sativus L.). The word saffron originated from 12th century old French term saffron, which derives from the latin word Safranum. Safranum comes from the Arabic word Asfar means yellow. In Sanskrit it has been the name of kumkum & kesar (Katzer, 2001). It is a prized culinary condiment, widely used in the cuisine of many European and Asian countries (Deo, 2003). Iran, India and Greece are the major saffron growing countries. Iran holding the distinction of having the major share (88.5 and 89.3 %) followed by India (5.7 % and 3.3 %) in terms of area and production (**Table 1**). Although the principle of saffron production in Kashmir and Khorasan are similar, there are many differences in the methods of production, processing and marketing (Kafi and Showket, 2007). In India, the Jammu and Kashmir is the only state that produces saffron with an area of more than three thousand hectares with a production of 91.24 quintals with an average land holding of 0.56 ha (Digest of Statistics, 2008).

The state is situated in the northern region of the Great Himalayan range spreading over 33-37 ºN latitude and 72-80 ºE longitude (**Fig. 1**). The state comprises 6.7 % of the total geographical area of the country, covering over 2.22 lakh square

Table 1 The world scenario of saffron production

Country	Area (ha)	Production (mt)	Yield (kg/ha)
Iran	43,408 (88.52)	174.00 (89.31)	3.98
India	3,143 (5.76)	6.86 (3.30)	2.23
Greece	1,000 (2.03)	4.30 (2.20)	4.30
Azerbaijan	675 (1.37)	3.70 (1.90)	5.48
Spain	600 (1.22)	5.70(2.60)	7.84
Morocco	500 (1.02)	1.00 (0.50)	2.00
Italy	29.4(0.06)	0.24 (0.12)	6.16
Total	49,037.4 (100)	195.40 (100)	(Average) 4.57

(Source: Acta Horticulturae no: 650 (May,2004)

Fig. 1 Map of Jammu & Kashmir state of India showing Saffron Area in red circles

km, of which about 30 % is under cultivation. The average size of operational land holding in the state is 0.66 ha, which is half than average operated holding size in India. Despite small geographical area, the state is blessed with diverse agro-climatic conditions, topography and natural resources for cultivation of a wide range of agro-horticultural crops. The climate of the state has made it well suited to the complex growing and blooming cycle of the saffron crocus.

Amongst various agro-based industries of the State, saffron also called golden condiment is the most expensive and prized spice and is regarded as pivotal economy regulating factor for the development of the state. As shown in **Table 2**. It is predominantly cultivated in District Pulwama (75 %), Budgam (16 %), Srinagar (7 %) and Doda (2.5 %) and Kishtwar. A legendary high value and low volume cash crop, saffron is a livelihood of more than 16,000 farm families in 226 villages with 61 % of holdings below 0.5 ha, 26 % size holdings between 0.5-1.0 and 13 % having holding size above 1.0 ha. Dwivedi and Tarunvir (2010) reported that the overall cost of cultivation was estimated $ 5,263/ ha for 9 years and net returns comes to $ 5,263 per ha respectively. The per hectare overall farm business income comes to $ 12,568 in 9 years from this crop, while family labour income was calculated to $ 8,477. The overall benefit-cost ratio comes to 1 : 2.57 on sample farms under study.

The majority of which are marginal farmers with no access to modern and advanced technologies being followed by other countries for improving the per unit area income of Saffron (Alam, 2008 and Nehvi and Wani, 2008).

The crop, grown since the 16th century in the area, is sold domestically and exported for use in food flavouring and colouring, pharmaceuticals, cosmetics and dyes. But over the past 15 years, there has been a drop in saffron cultivation area as well as in production yields with a decline of about 40 percent. As presented in **Fig. 2**. The saffron area has gone down from about 5,700 hectares to just around 3,800 hectares and the productivity too has dipped from 3.13 kg per hectare to 2.50 kg/hectare. The erratic rain and snowfall, likely related to climate change, have played havoc with the flowers, cutting Khalik's yields by almost half over the last decade. The urbanization and unplanned construction of residential houses in the midst of saffron fields during the last two decades is one of the major causes for shrinking of acreage. Other reasons that threaten the costliest cash crop of the state are the lack of irrigation facilities, poor management of techniques adopted by the growers and lack of postharvest management that have led to low productivity. However, there is a considerable possibility of increasing production through mechanization in saffron production.

Presently, saffron cultivation is not highly mechanized, although it requires high labour input during the most important growing phases,

Fig. 2 Production and Productivity of Saffron in Jammu & Kashmir Since 1997-98

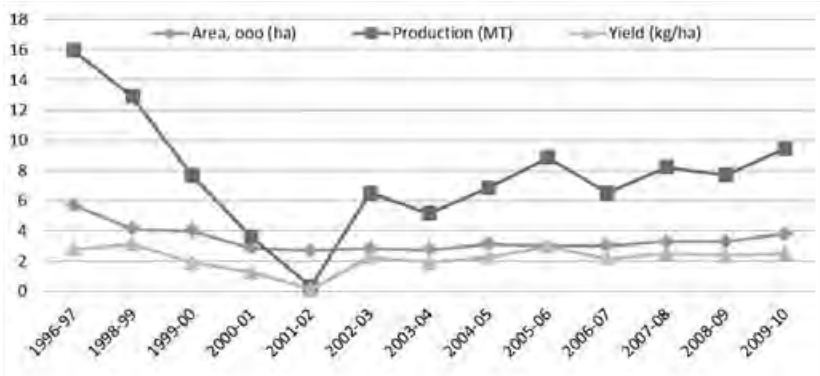

Table 2 District wise area, production and productivity of Saffron in J & K

District	Major Villages growing saffron	Area under saffron, ha	Production, MT	Productivity, kg/ha	No. of families involved in Saffron cultivation
Pulwama	Khrew, Ladoo, Dussu, Lathipora, Sambora, Awantipora, Koil, Pampore,Balhuma,Wayun, Munpur, Mueej, Konibal, Dus, Zundhur, Letpur, Sombar, Baras and Ladu	3,200 (84.5)	8,014 (84.7)	2.50	9, 000 (55.46)
Budgam	Chadura, Nagam, Lasjan, Ompora and Kralpura	300 (7.9)	750 (7.9)	2.50	1,227 (7.56)
Srinagar	Zewan and Zawreh	165 (4.4)	404 (4.3)	2.45	732 (4.51)
Kishtwar	Poochal, Bemarnag, Matta, Hidyal, Berwar, begana, Hatta, Sangramabatta, Cherhar, Nagni, Layel, Doda (Namil, Gatha)	120 (3.2)	294 (3.1)	2.45	5,310 (32.72)
Total		3,785 (100)	9,462 (100)	2.50 (Ave.)	16,229 (100)

(Source; Directorate of Agriculture, J&K, Nehvi *et al*., 2008)

there are no machines capable of totally mechanizing this crop, and research up to now has always tried to adapt existing machinery to reach individual phase of its cultivation, rather than design specific machines. Almost all the field operation for saffron cultivation in Kashmir valley are carried out manually using indigenous tools mainly Rampa or Khurpi for Weeding, Tangru-small and large for hoeing and Spade (Zoni) for movement of soil/ opening drain. For rejuvenation and fresh planting of saffron corm digging, sowing, land preparation and bed forming are the most labour consuming and expensive operations respectively. Labour in monetary terms on an average comes to $ 2,990 /ha for existing saffron fields and $ 4,645 /ha for rejuvenation and fresh planting of saffron (Daniyal and Zarka, 2012).

Land Preparation and Bed Forming

Mostly all the Saffron fields are prepared by ploughing with bullock drawn plough, locally called as 'Albani'. The ridge and furrow formation is also accomplished manually by using spade (**Fig. 3**). Ploughing is done in the same furrow to achieve required depth and tilth as well as to keep the field clean in every month from April to September for fresh planting. The bullock drawn plough is having a field capacity of 0.03 ha/h and 30 man-days/ha are required for land preparation for fresh planting (**Fig. 3**). Manual labour utilized in land preparation amounts to a heavy expenditure of $ 510/ha. The high amount involved can be reduced by using the tractor operated cultivators and rotavators with a working capacity of 0.8 -1ha/h to 0.2-0.3 ha/h respectively resulting in saving an amount of $ 510/ha. For Bed making and forming 50 man-days/ha are required using spade manually. This operation accounts to an amount of $ 400/ha. Manual bed forming can be replaced by using raise bed planter with a field capacity of 0.25 ha/h. The machine can be operated at a forward speed of 2.5 km/h to 3 km/h. It consists of three bed formers, two beds can be formed in a single run (**Fig. 4**). The cost of the machine is $ 1,400 approximately (Daniyal and Zarka 2012).

Corm Digging and Corm Sorting

At the end of planting cycle (7-10 years) the saffron corms are gathered from the field. Corms are dug out in the second fortnight of August and Planting is done in the first fortnight of September. Corm digging is done manually with the spade locally called as "Zoni" having 80 mm to 150 mm size with a field capacity of 0.006 ha/h (**Fig. 5**). Corm digging is one of the most labour and money consuming operation and requires about 160 man-day/ha for digging corms only. This operation amounts to an expenditure of about $ 1,280/ha. This operation can be mechanized by a power tiller operated potato digger with a field capacity of 0.15 ha/h and resulting in saving an amount of $ 300/ha.

As shown in **Fig. 6**, corm sorting is done manually at farm houses and it consumes about 50 man-days/ha. Electronic corm sorter can be used for this operation and need to be introduced and popularized. Manual labour utilized in sorting of saffron corms amounts to an expenditure of $ 400/ha.

Corm Planting

At the advent of spring, i.e. in late March, which lasts till April, the field is repeatedly ploughed either by a plough, or twice by tractor at an interval of about 20 days. Subsequently, in August levelling and hoeing operations are carried out. Fields are pulverized three to four times. Ideally 15-20 t of well-decomposed farm manure per hectare of land are applied and thoroughly mixed into the soil before the last tillage operation (Mir, 1992 and Munshi *et al*., 2001). The field is laid out into 1.5-2 meter wide strips (normally 2-3 m long) across the field with slopes along the sides, which end up in 30 cm wide 20 cm deep drainage channels on both sides. These channels help in draining out the excess water. Corm planting is done in the last week of August to first fortnight of September after grading of corms (Munshi *et al*., 2001 and Zargar, 2001). Manual labour (**Fig. 7**) required for planting is about 100 man-days/ha and amounts to a heavy expenditure of $ 800/ha. Corms are planted in rows at a spacing of 20 × 10 cm and

Fig. 3 Traditional Implements

Fig. 4 Ridge forming by tractor drawn ridger

Fig. 5 Traditional corm digging

Table 3 Identified Mechanization gap for saffron production in Jammu & Kashmir

Operations	Implements being used	Improved implements suggested	Power source
Land clearing	Dao	Light weigh grass/ bush cutter	Small engine
Land preparation	Spade, shovel	Ridger plough	Animal
	Animal drawn Shalimar plough	Light weight rotary tiller	Small engine
Ridge/ bed formation	Spade, bullock drawn plows 'Albani'	Animal drawn ridger	Animal
		Power tiller operated ridger	Small engine
Corn digging	Traditional Implements, Spade, 'zoni'	Potato digger, ground nut digger	Power tiller
Corn sorting	Manually	Electronic corn sorting	
Corn planting	Manually	Saffron planter	Self propelled
Weeding and Hoeing	Traditional impliments, phuhur, Ramba/ khurpi, Tangru, spade, zoni	Wheel hand hoe, Power weeder	
Rodent control		Rodent fumigator	
Harvesting	Manually Picked	Saffron picker	
Separation	Manually		
Drying	In Shade	Hot Air Dryer, Electronic Dryer, Low Cost Dryer Using Lpg	

at a depth of 15 cm with 1 corm/ hill or with a planting geometry of 25 × 15 cm with 2 corms/hill maintaining a planting density of 5 lakh corms/ha with a seed rate of 50 quintals/ha (Nehvi *et al*., 2011). Planting depth varies from 10 to 20 cm. Shallow planting generates greater number of buds which produces greater number of corms. In deep ploughing, there are less sprouts but of larger size. Position of corms with apical bud upward is important for planting of corms. Corms are sown in deep furrows at a spacing of 20 cm made using bullock-drawn plough. By suitably modifying in onion/potato/tulip planter, raised bed planting saffron corm can be planted (Alam, 2008). The working time with this planter per 1,000 m^2 arranged in ridges is 5 hours, compared to over 100 hours for manual planting (Galigani and Pegna 1999). This machine can reduce time for planting to only 50 h/ ha as compared to 800 man-hours/ ha. Thus, it would result in saving of time, labour and money for the farmers. The saffron corms are placed by hand in the scoops, which are moved in horizontal rows by a wheel resting on the ground. The chains are lowered into the ground to deposit the corms in the furrows opened by a furrowing implement located at the front and at the rear double disc covering devices are used. The orientation of corms is the major problem in these methods.

Irrigation Management

Water is the crucial factor for successful saffron production. Since, saffron in Jammu and Kashmir is exclusively cultivated as rainfed crop (**Fig. 8**). Therefore, failure of rains in August and September is reflected in crop failure. Studies in Kashmir shows that saffron should be sprinkler irrigated @ 700 m^3/ ha to be distributed over 10 irrigations at weekly interval. First seven irrigations are most crucial for the accelerated growth and facilitation of flowering. Timing of this phase of irrigation (pre-flowering or pre-sprouting) is very important and should be started from last week of August till 15th October based on climatic conditions, otherwise flowering and vegetative growth may coincide which may interfere with the picking of flowers. For first seven irrigations about 490 m^3/ha of irrigation water is required. To boost vegetative phase for enhanced corm production 3 irrigations with a total water requirement of 210 m^3/ ha should be applied starting from 8th November (Nehvi *et al*., 2011). Pressure Compensating sprinkler irrigation system is recommended for saffron cultivation. Proper and timely irrigation management in saffron can increase the present production from 2.5 kg/ha to 5 kg/ ha. Thus, it will benefit the saffron

Fig. 6 Manual corm sorting

Fig. 7 Manual corm planting

Fig. 8 Sprinkler Irrigated field

grower and increasing a return from $ 5000/ha to $ 10,000/ha. Installation and establishment cost of the pressure compensating sprinkler irrigation system is $ 1,200 to $ 1,400/ha (Daniyal and Zarka, 2012).

Weeding and Hoeing

Weeding and hoeing are the most laborious operation in saffron cultivation followed by separation and picking (harvesting) respectively. About 485-500 man-days/ha are required in saffron farming from land preparation to drying for fresh planting and for existing saffron fields about 395-410 man days/ha are required for the same. Hoeing is the most expensive operation in saffron farming in Kashmir requiring 95 man-days/ha (2 hoeings @ $8/day/labour) followed by Separation (110-man days/ha @ $5/day/labour), Picking (100-man days/ha @ $5/day/labour, between 21st October to 15th November) and Weeding (40-man days/ha @ $5/day/labour).

Weeding and hoeing are done manually (**Figs. 9** and **10**), accounts for a major labour cost component (32 %) of total cost input in existing planting. Manual labour utilized in weeding and hoeing amounts to a heavy expenditure of $ 800/ha. Weeding is done in the month of June and requires about 40 man-days/ha. Two Hoeings are done in the month of June and September and requires about 95 man-days/ha. These operations can successfully done with the help dry land weeder and wheel hoes designed for clay loams. For hoeing two wheel light weight tractors and small power weeders can also be used (**Fig. 11**).

Rodent and Pest Management

Rodents have been found major cause of concern in saffron up to 40-50 % (Manzar *et al*., 2008). The improved rodent fumigators have been developed to control the rodents.

Harvesting and Picking Operation

Harvesting of saffron includes picking of flowers that is performed manually. Mechanical harvesting is hindered because of the damage of flowers, which grows just a few cm alone the soil surface and usually appears with/or/after the leaf appearance (**Fig. 13**). Flower-picking starts as soon as they appear in the field (**Fig. 14**). The flowers are not picked daily but once in four days, before 9 o'clock in the morning. This method of flower collecting in Kashmir might cause reduction in quality as well quantity of yield (Ganai,, 2001 and Mir, 2001).

Postharvest Operations

Postharvest operations include separation drying, processing and packaging. Kashmir saffron is well known for its intrinsic quality but traditional postharvest practices followed by the farmers result in postharvest losses to the tune of 30 % with inferior product quality. Postharvest practices result in a recovery of 20-22 g of saffron from 1.0 kg of fresh saffron flowers. These operations require about 20 man-days/ha.

Fig. 9 Manual weeding and hoeing

Fig. 10 Crust breaking by "ZONI"

Fig. 11 Power weeders for weeding

Fig. 12 Rodents control through fumigator

Fig. 13 Saffron in flowering and vegetative phase

Fig. 14 Manually harvesting and picking of Saffron flower

Stigma Separation

This is the most important step of saffron processing as 30 % of yield losses together with quality deterioration occur here. Generally the harvested flowers are heaped in one room and all family members from youngest to oldest are involved in this operation. Pistol is plucked from flowers and separated stigmas are separated on cloth for drying process (**Fig. 15**). This process is done within 6-8 hours to recover 95-100 % saffron. After 24 hours only 40-50 % and after 72 hours 0 % saffron is recovered (Nehvi *et al*., 2004). Harvesting of flowers at right stage and separation of stigmas from flowers at right time holds the key to prevent deterioration in loss of crocin in the final product. The mechanized effort in this direction will definitely be economical viable as the manual cost is high.

Drying of Saffron Stigma

The drying is carried under shade which generally takes 27-53 hours to dry to a safe moisture level of 8 %. This results in quality deterioration. Modified hot air dryers can be successfully used resulting in quality controlling and efficient drying of saffron (**Figs. 16** and **17**). Hot-air saffron tray dryer having four trays of 1 m^2 each with supplement heating using LPG stove is circulated by a blower (**Fig. 18**). Hot-air saffron dryer can dry saffron even in an inclement weather. Thus reducing the time and labour involved in this operation. These dryer works on hot air flow in absence of direct sunlight. The dryer helps in retaining the original color of saffron in absence of sun light. Temperatures up to 80 ºC can easily be controlled. These dryers mainly work on two heating elements of 1 kW each and two exhaust fans for circulating hot air.

Technological Gap and Future Suggestions for Improving Mechanization Status

Maximum operation in saffron cultivation can be mechanized by suitably modifying the existing onion/potato/tulip planters, for making raise beds raise, bed planter can be used. It is rather excessive demanding mechanization through appropriate tools, equipment and machines which minimizes the drudgery of labors so that new generation continues to practice saffron cultivation in Jammu & Kashmir state. Farm mechanization offers great scope for profitability and income in saffron production. Mechanizing these stages does, however, assume a certain degree of modernization in saffron cultivation, to move it from traditional agriculture on a small scale carried out by small farmers on marginal land, to a more dynamic agriculture in Kashmir valley. The dissemination of the technologies together with support from the Govt. to promote their adoption by the saffron growers should enable revival of this prominent industry.

Hussain *et al*. (2010) also reported that the technological gap of small saffron growers had positive and significant relationship with attitude and socio-economic status while as a positive and non-significant relationship of technological gap with age and caste. The technological gap of medium saffron growers had a significant and positive relationship with age, socio-economic status, knowledge and attitude. The technological gap of big saffron growers had significantly negative relationship with extension contact.

Conclusions

The J & K state possesses a huge potentiality to adopt selective mechanization rather than sweeping mechanization. Presently the saffron cultivation is not highly mechanized, although it requires high labour input during the most important growing phases. The farmers growing saffron face difficulties in timely completion of field operations due to lack of mechanization inputs like improved implements for

Fig. 15 Manually Separation of stigma from the flower

Fig. 16 Solar tunnel saffron dryer

Fig. 17 Low cost solar dryer

Fig. 18 Low cost hot-air dryer with LPG stove

planting, harvesting/ picking, separation and processing equipment. It is rather excessive demanding mechanization through appropriate tools, implements and machines which not only reduce excessive labour but remove drudgery so that new generation continues to practice saffron cultivation in Kashmir region. The application of mechanization technology would increase saffron productivity. Consequently, labour tied up with manual farm operations would be released to higher value activities.

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Design and Evaluation of Mango Stone Decorticator

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Abstract

A mechanical mango stone decorticator was designed, fabricated and tested. The machine consists of the frame, feeding chute, cylinder assembly, concave, discharge outlets, blower and drive unit. Cylinder speed (200, 250 and 300 rpm), feed rate (150, 200 and 250 kg/h) and moisture content (9.62, 15.02 and 17.89 % d.b.) were taken as the study variables. The best set of conditions under which the decorticator could be operated was at a cylinder speed of 250 rpm, feed rate of 200 kg/h and at 9.62 % moisture content (d.b.), where the machine was found to have decortication efficiency and kernel breakage of 93.91 % and 68.12 %, respectively. All the selected variables were found to have statistically significant effect on the performance indicators.

Introduction

The progressive growth of food processing industries in India has brought forth the problem of effective disposal of processing wastes. Studies have shown that the effective utilization of some of these wastes in other countries has resulted in the production of valuable products. Proper utilization of food processing wastes is necessary not only for the development of agro-based industries, but also to make these units economically viable (Okonko *et al*., 2009). Mango stone is one of those by products which could be further processed into useful products.

Mango (*Mangifera indica L*.) is one of the important fruit crops grown in India and acquired a name "King of Fruits" (Thind *et al*., 2002). India ranks first in the world production. As mango is a seasonal fruit, about 20 % of fruits are processed into products such as puree, nectar, pickles and canned slices, which have worldwide popularity (Ajila *et al*., 2007). Mango peel and stone are the major byproducts of mango processing, accounting for 35 to 60 % of the total fruit weight. Mango stone is composed of outer hard and fibrous pericarp (shell), and soft and nutritive inner kernel. Weight of mango stone varies between 10-25 % depending upon the variety under consideration. Mango kernel forms 45 to 75 % of mango stone and 20 % of the whole fruit (Mirghani *et al*., 2009).

With the development of the mango processing industries in India, large quantities of mango stones are available at factory sites which are not being commercially exploited and hence become a source of pollution. Since this creates a serious disposal problem, ways for its productive utilization have been explored. Review of earlier research work reveals that mango kernel could be a source of fat, natural antioxidants, starch, flour and feed (Mittal and Singh, 1982; Maninder *et al*., 2004; Moharram and Moustafa, 1982; Arogba, 2002).

Decortication is the process of separation of shell/seed coat from the seed or kernel (Pradhan *et al*., 2010). Manual decortication is a time consuming, tedious and labour intensive. Moreover, quantity and quality of out-turn depends upon the skill of the person (Jain and Kumar, 1997). This emphasizes the need for the development of mechanical equipment for the mango stone decortication. Researchers have worked on different types of decorticating system/sheller for agricultural produce such as cocoa (Adewumi and Fatusin, 2006), sunflower (Gupta and Das, 1999), maize (Nkakini *et al*., 2007), groundnut (Oluwole *et al*., 2007), etc. but very few studies have been done on decortication of mango stone in particular. Hence the present study was undertaken with the objective to design, develop and evaluate a

mechanical decorticator for mango stone.

Materials and Methods

Engineering Properties of Mango Stone and Kernel

It is important to consider the Engineering properties of agricultural materials for the design, development and operation of equipments employed in their processing (Mohsenin, 1970). Therefore, engineering properties of mango stone and kernel that were relevant for designing a decorticator were determined by the methods described and used by various researchers for similar kind of agricultural materials. These properties include moisture content, axial dimensions, static coefficient of friction, angle of repose and crushing strength (Kaleemullah and Gunasekar, 2002; Olaniyan and Oje, 2002; Hassan *et al*., 2009; Balasubramanian, 2001). Two varieties of mango viz. Totapuri and Neelum, which are extensively used in processing industries, were selected for acquiring design relevant data (**Table 1**).

Design Considerations

The mechanics of mango stone decorticator include impact and shearing. Following factors were considered in the design of the mango stone decorticator.

1. Materials of adequate strength and stability were used for fabrication (i.e. mild steel).
2. The machine was designed to have a maximum capacity of 250 kg of mango stone per hour so that machine could be affordable for medium and small industries.
3. Locally available materials were used in the fabrication of the components.

Cost of items and materials used for fabrication were given due consideration with the ultimate aim of utilizing the cheapest available materials, yet satisfying all strength requirements.

Design of Machine Components

The relevant physical and mechanical properties of mango stone and kernel were obtained as the basic design data. Design of the feeding chute was based on the flow characteristics of the fruit. Experiments were carried out for determining the engineering properties of mango stone revealed that the flow characteristics like sphericity varied between 0.43-0.51 and angle of repose ranged between 33.42º and 38.17º at various moisture levels. Therefore, the feeding chute was fastened at an angle of 40º for easy flow of the mango stones. Similarly, an experiment was carried out to determine the force required to break the stone. The crushing force so deduced 412 N was employed in the subsequent design and the selection of machine components. The size of openings in the concave was based on the axial dimensions of the kernel. The dimensionless numbers (Eqs. 1-3) established by Pustygin (1948), were used to determine the diameter of the decorticating section and size of pegs. For the purpose of design calculations, speed of the cylinder was taken as 350 rpm. The formulae used in the calculation of some of the parameters of various machine components are given in the equations 4 to 9 below (Allen *et al*., 1988; Khurmi, 2001; Khurmi and Gupta, 2006).

$$L / D = 3 \text{ to } 4 \quad \ldots(1)$$

$$L_p / d = 0.25 \text{ to } 0.4 \quad \ldots(2)$$

$$[(\pi \times d_p^2 / 4) \times z] / L_{eff}^2 = 7.5 \times 10^{-3} \quad \ldots(3)$$

$$P = (2\pi \times N_1 \times T) / 4500 \quad \ldots(4)$$

$$T = \text{force} \times \text{distance} \quad \ldots(5)$$

$$M_d = [(M_d \times i) / \eta] \times K_{ov} \quad \ldots(6)$$

$$i = N_2 / N_1 \quad \ldots(7)$$

$$M_e = P \times 4500 / (2\pi \times N_2) \quad \ldots(8)$$

$$M_d = (\pi / 156.8) \times f_s \times d_s^3 \quad \ldots(9)$$

Where, D is the diameter of the threshing chamber, mm; L the total length of the cylinder, mm; L_{eff} the effective length of cylinder, mm; d the diameter of cylinder, mm; d_p the diameter of peg, mm; z the number of pegs on the drum; L_p the length of the peg, mm; P the power of main shaft, hp; N_1 the cylinder speed, rpm; T the torque applied, kg m; M_d the design turning moment; M_e the turning moment of motor shaft; i the transmission ratio; N_2 the motor speed, rpm; η the transmission efficiency; K_{ov} the coefficient of over-

Table 1 Engineering properties of mango stone and kernel of two varieties

Properties	n	Mean values			
		Totapuri		Neelum	
		Stone	Kernel	Stone	Kernel
Moisture content (% d.b.)	5	9.64 ± 0.36	14.94 ± 0.21	9.51 ± 0.43	14.39 ± 0.27
Length (mm)	40	98.29 ± 16.31	48.28 ± 9.16	76.15 ± 13.83	40.18 ± 7.47
Width (mm)	40	41.13 ± 10.38	28.72 ± 8.17	39.92 ± 8.39	21.99 ± 4.42
Thickness (mm)	40	18.65 ± 8.09	12.02 ± 1.64	19.52 ± 6.72	13.38 ± 1.96
Static coefficient of friction on galvanized iron	5	0.69 ± 0.01	0.51 ± 0.01	0.7 ± 0.03	0.51 ± 0.01
Angle of repose (degrees)	5	36.34 ± 1.83	20.27 ± 1.05	34.55 ± 1.13	21.38 ± 0.92
Crushing strength (N)	5	315.5 ± 12.2	474 ± 35.4	384.3 ± 32.4	477.1 ± 27.4

n is the number of samples. Data are mean values ± standard deviation.

loading; f_s the maximum permissible shear stress, kg/cm^2; d_s diameter of the shaft, m.

The calculations showed that cylinder length of 1 m and diameter of 165 mm was appropriate for the design. Similarly optimum peg length and diameter was found to be 58 mm and 12 mm respectively. Cylinder speed of 350 rpm was considered for design calculations. The Shaft diameter of 30 mm was found sufficient to overcome the shaft load. Ball bearings were used for reducing the frictional effect as indicated by the Anti-friction Bearing manufactures Association (Shigley, 1989).

Fabrication of the Machine

Based on the engineering properties of the selected mango verities and other information from literature, a mango stone decorticator was designed, machine components were fabricated and assembled as per detailed drawing shown in **Fig. 1**. The machine was developed to operate on the principle of impact and shear. It consists of frame, feeding chute, cylinder assembly, concave, discharge outlets, blower and drive.

The main frame was fabricated using Mild steel angle iron (50 × 50 × 6 mm) and well structured and braced to provide rigidity to mount and support all the other parts of the decorticator and to withstand vibrations during operation. The feeding chute of trapezoidal shape was mounted on decorticating section at an inclination of 40º.

A hallow mild steel cylinder was co-axially fastened at the centre of the solid shaft by using two mild steel circular plates. Along the 15 % of the total cylinder length, mild steel flat was fastened in vertical position with a pitch of 102 mm, for positive feeding of mango stone inside the decortication section. Mild steel pegs of 12 mm diameter and 58 mm length were welded on to the cylinder along its length in four equally distributed rows with 17 pegs in each row. Centre to centre distance between adjacent pegs was 50 mm. Pegs of same size were fixed on one side of the top of the frame, such that the pegs on rotating cylinder would pass in between these stationary pegs during rotation. Main shaft was fixed on the top of the frame by means of pillow block bearings. Schematic diagram of cylinder assembly is shown in **Fig. 2**. Cylinder housing was provided over the entire length of main frame top to enclose decortication section. Two semi circular mild steel plates formed side walls of the housing cover. A clearance of 25 mm was provided between the cover and tip of the pegs.

Mild steel sheet of 14 gauge thickness with oblong openings (50 × 17 mm) was used as concave. Clearance of 12 mm was provided between sieve and peg. The concave was fixed to the main frame such that it aligned in line with cylinder cover.

A blower was installed in the unit for the pneumatic separation of shell from kernel. Solid shaft was used in the fabrication of blower. Two metal square blocks of 51 mm with 38 mm bore were fastened to the blower shaft to which fan blades were attached. Flat rectangular metal plates (4 No.) of size 813 × 102 mm were used as fan blades. Blower shaft was mounted on the side of the main frame by means of pillow block bearings. A Blower housing of 381 mm outer diameter and 914 mm length having an inlet opening of 200 mm on both the sides was made using 18 gauge mild steel sheet. A three phase motor of 5 hp is installed to drive the cylinder and blower. From the motor, the

Fig. 1 Mango stone decorticator assembly and parts

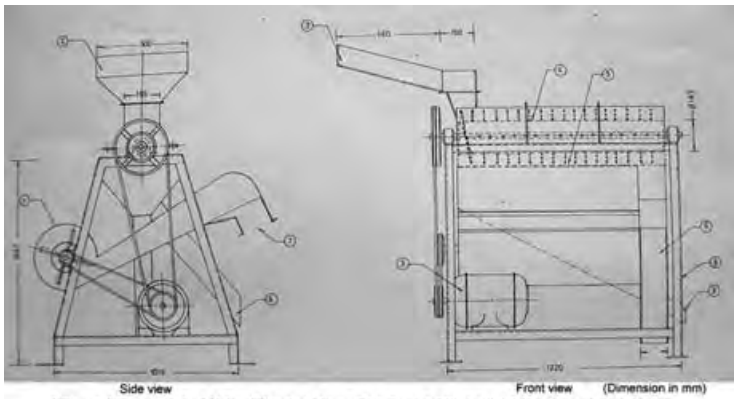
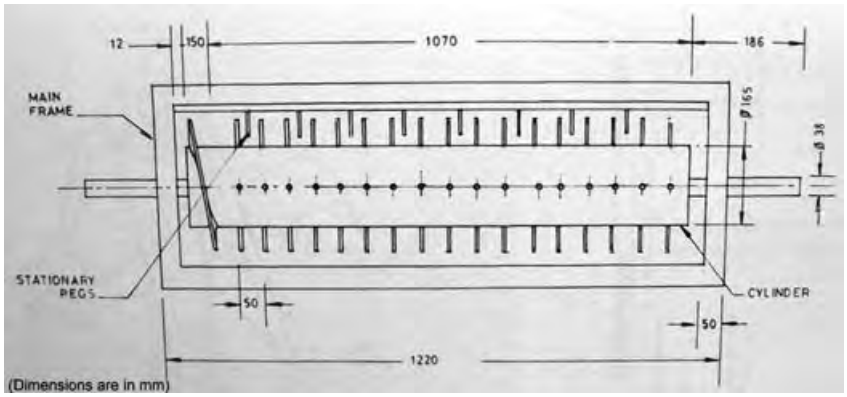


Fig. 2 Schematic diagram of cylinder assembly



power could be transmitted through V-belts and pulleys.

Principle of Operation

Mango stones are fed into the cylinder and concave assembly through feeding chute. During the decortications process the stationery pegs and cylinder cover hold the stones and the rotating pegs impart impact and shear force on them which leads to failure of mango stone shell. By the time the mango stones pass from feed end to discharge end, stones get decorticated, shells discharge through the shell outlet and the kernel passes through the sieve below. Blower assembly helps in separating kernel from dust and shell which is passing through the sieve.

Performance Test Procedure

Mango stones obtained from the disposal sites of several mango processing industries of Krishnagiri district of Tamil Nadu (India) were used for the performance evaluation. The following variables were selected for carrying out the performance analysis:

Variables	Level
Feed rate, kg/h	150, 200 and 250
Moisture content, % d.b.	9.62, 15.02 and 17.89
Cylinder speed, rpm	200, 250 and 300
Performance indicators:	Decortication Efficiency and Kernel Breakage

Moisture content of mango stone shell was considered for performance tests. The initial moisture content was determined (Balasubramanian, 2001) and was found to be 9.62 % d.b. Samples were moistened with a calculated quantity of water (Pradhan *et al.*, 2009) and conditioned to raise their moisture content to desired level. The tests were performed by connecting the decorticator to a variable speed motor set up. Feed rate was controlled manually by feeding a known quantity of material at a given time interval.

After decorticating a known quantity of material (Q_0), the materials from all the outlets were carefully collected and grouped into three categories, namely unshelled mango stones (Q_1), whole kernel (Q_2) and broken kernel (Q_3). Kernels with 3/4th of their total length were considered as whole kernel. Perfor-

Fig. 3 Effect of moisture content on performance indices: a decortication efficiency, b kernel

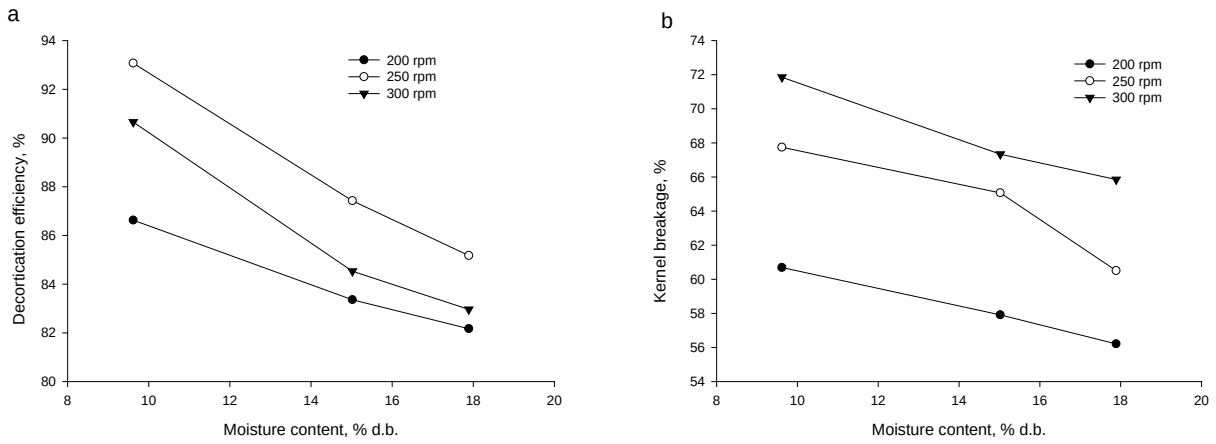
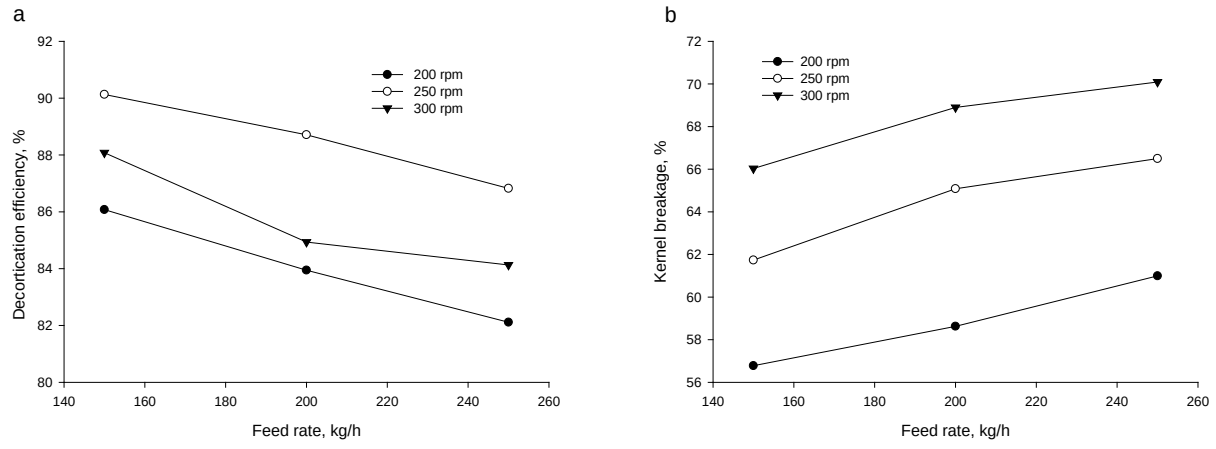


Fig. 4 Effect of feed rate on performance indices: a decortication efficiency, b kernel breakage



mance indicators were calculated using the formulae given below:

$$\text{Decortication efficiency (\%)} = [1 - (Q_1 / Q_2)] \times 100 \quad \text{.....(10)}$$

$$\text{Kernel breakage (\%)} = \{Q_3 / (Q_2 + Q_3)\} \times 100 \quad \text{.....(11)}$$

Results and Discussion

Effect of Moisture Content on Performance Parameters

The decortication efficiency and kernel breakage decreased with increase in moisture content (**Fig. 3**). This decrease in decortication efficiency and kernel damage is attributed to the loss of brittleness in Mango stone and kernel owning to higher moisture content which makes it soft and resistant to mechanical damage or rupture and hence increases the crushing strength. Studies conducted by Mittal and Singh (1982) have proved similar effects of moisture content on mango stone decortication. The results are also in line with the studies carried out by Daya (2001) on chestnut decortication, Orji *et al.* (2001) on breadfruit shelling, Atiku *et al.* (2004) and Oluwole *et al.* (2007) on bambara groundnut. Inverse relation between the moisture content and decortications efficiency was evident from the studies done by Pradhan *et al.* (2010) on jatropha fruit, Anil and Sirohi (2003) on linseed crop.

Effect of Feed Rate on Performance Parameters

Fig. 4 reveals the effect of feed rate on decortication efficiency and kernel breakage. From the figure it can be observed that the decortication efficiency decreased with increase in feed rate. This might be due to cushioning effect or reduction in residence time. Results obtained in this study are on par with the results observed by Atiku *et al.* (2004) for bambara groundnut, Oluwole *et al.* (2004) for sheanut, Jekayinfa and Durowoju (2005) for mango stone. With the increase in feed rate kernel breakage also increased. Analogous report of increase in mechanical damage with increase in feed rate was observed by Oluwole *et al.* (2004) for sheanut, Jekayinfa and Durowoju (2005) for mango stone.

Table 2 F-ratio for the result of the performance tests

Source of variation	F-ratio	
	Decortication efficiency	Kernel breakage
Cylinder speed (N)	142.589*	360.60*
Feed rate (F)	136.115*	35.50*
Moisture content (M)	191.092*	197.60*
Interaction		
NF	83.781*	77.16*
FM	69.289*	74.16*
NM	63.408*	53.98*
NFM	67.503*	67.04*

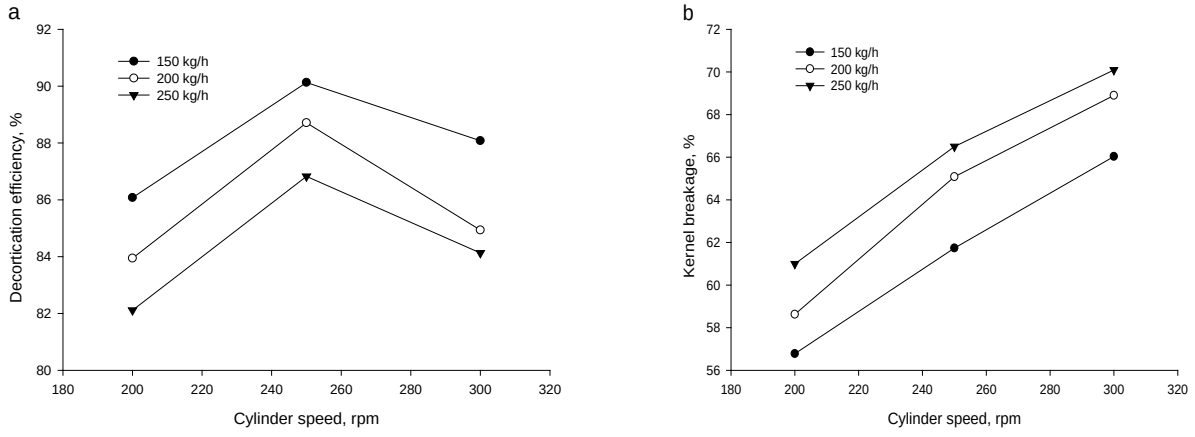
*Significant at 1 % level

Effect of Cylinder Speed on Performance Parameters

The effect of cylinder speed on performance indices is shown in **Fig. 5**. The decortication efficiency initially increased with an increase in cylinder speed and then decreased. The low decortication efficiency at minimum speed may be due to the low impact force applied on to the mango stones which results in partially shelled or unshelled stones. Reduced efficiency at higher cylinder speed is due to shorter residence time of mango stone in the decortication section. On the other hand, percentage kernel breakage increased with the increase in speed. This may be due to increase in shear and impact force on the mango kernels at higher speed. Analogous results on the effect of cylinder speed were observed by Jain and Kumar (1997) for cashew nut shelling, Singh (2003) for water chestnut, Adewumi *et al.* (2007) for grain legumes.

Analysis of variance shows that the variables have significant effect on performance indicators at 1% level of significance (**Table 2**). The interactions among the variables are

Fig. 5 Effect of cylinder speed on performance indices: a decortication efficiency, b kernel breakage.



also significant at same level of significance.

Conclusions

A mechanical mango stone decorticator was designed, fabricated and tested. The results of the study showed that the moisture content of the mango stone, feed rate and cylinder speed significantly affected the decorticator performance. Decortication efficiency and kernel breakage decreased with increase in moisture content. Increased feed rate led to decreased decortication efficiency while increasing the kernel breakage. The decortication efficiency initially increased with an increase in cylinder speed and later decreased with the further increase in cylinder speed, where as the kernel breakage was found to be directly proportional to the cylinder speed. It was found that the best set of conditions under which the decorticator could be operated was at stone moisture content of 9.62 % d.b. with feed rate of 200 kg/h and the cylinder speed of 250 rpm. Under these conditions 93 % of decortication efficiency could be achieved with the kernel breakage of 68.12 %.

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Design, Development and Testing of a Group Milk Feeder for Kids

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Abstract

All the kids which are unable to suckle milk from their mother due to reasons as non acceptance by their mother due to lack of milk let down resulting in low milk production, weak kids, death of dam and mastitis. Therefore, kids are bound to be reared on artificial milk feeding to reduce their mortality. In the present study, efforts have been made to develop a Group Milk Feeder for these kids so that they could suckle milk from feeder comfortably. On the basis of initial design of Group Milk Feeder a refined feeder was developed while utilizing the feed backs obtained during the study.

Introduction

The success of goat farming is highly influence by pre-weaning mortality. The pre-weaning mortality may range from 7 to 51 % and the greatest number of deaths occurs during the first and second day of life (Mellor and Stafford, 2004). In organized goat farms, lower birth weights, dams with insufficient milk and lack of husbandry knowledge were considered the main factors responsible for higher kid mortality (Husain *et al*., 1995). Alexander and Peterson (1961) attributed 14 % of lamb deaths due to maternal abandonment, 33 % due to lamb behavior and 52 % due to a combination of both factors. The few probable reasons for rejection of kids by doe are (1) failure to accept the new born completely by the doe within 24 hours because of non experience in primiparous does, tickling effect, injury to udder etc. (2) lack of milk production or milk let down (3) does having history of low milk production if gives birth to twins, one of the kid in considered as orphan (4) weak kids having less than 1.00 kg body weight (5) death of dam (6) mastitis. All such kids which are rejected by their mothers by any of such reasons are considered as orphan kids. All these orphaned kids are bound to be reared by artificial milk feeding systems such as bottle feeding or group milk feeding devices to reduce pre-weaning mortality. In developed countries generally milk bars/automatic milk feeding devices are used to rear kids. However, such devices are still to be used in Indian farms. Therefore, efforts have been made in the present study to design and develop a group milk feeding device with locally available materials, so that milk feeding to orphaned kids could be accomplished with reduction in man-power required in milk feeding operation.

Materials and Methods

A Group Milk Feeder (GMF) suitable for six kids was developed under the study. The equipment was tested for its suitability for the milk feeding to kids. Labour required in morning and evening milk feeding in man-minute/feeding at 15 days interval was recorded under natural, bottle and group milk feeding for comparison. In natural feeding the kids remained with their mother, therefore, there was no labour requirement. Observations were made for the possible improvement in the initially designed Group Milk Feeder. On the basis of observations made, a second improved prototype was developed under the study.

Design and Development

A group milk feeder circular in shape suitable for six kids was developed under the study while using the mild steel sheet. The feeder was cylindrical in shape with a diameter of 60 cm. It was circumferentially divided into six equal segments. Each segment was provided with a polypropylene rubber nipple with suitable assembly. Each nipple assembly was quickly detachable for necessary cleaning and sterilization of rubber nipples. The base of the GMF was concave in shape which

Table 1 Labour requirement in different milk feeding operations at different stage of age (man- min/feeding)

Days	Bottle Feeding		GMF Feeding	
	Morning	Evening	Morning	Evening
0 - 15	2.429 ± .105	2.314 ± 1.25	0.921 ± .055	0.878 ± 0.05
15 - 30	1.584 ± 0.025	1.429 ± 0.023	0.475 ± .022	0.435 ± 0.023
30 - 45	1.327 ± 0.006	1.317 ± 0.008	0.451 ± 0.010	0.407 ± 0.015
45 - 60	1.312 ± 0.0009	1.291 ± 0.010	0.431 ± 0.007	0.408 ± 0.003
60 - 75	1.216 ± 0.005	1.201 ± 0.006	0.421 ± 0.005	0.406 ± 0.004
75 - 90	1.167 ± 0.007	1.165 ± 0.008	0.42 ± 0.002	0.403 ± .006

was divided into six compartments as shown in **Fig. 1**. A measured quantity of 250 ml milk was poured into each compartment for necessary supply to kids. The kids in action are shown in **Fig. 2** while consuming the milk from the GMF. The concave base of system did not allow any retention milk on the base of compartment. The system was having telescopic adjustment of two pipes such as to adjust the height of nipples.

On the basis of observations made on first prototype of GMF, further modifications were made in the system and a second prototype was developed as depicted in **Fig. 3**. This system was having convex base opposite to concave base as provided in earlier model so that all milk is accumulated at the outer boundary of GMF. Nipples were provided at the outer boundary of device and were tilted at some angle where as nipples were projecting straightway downward in the first model. This tilt facilitated comfortable suckling of milk by the kids. Moreover, a circular pan was provided at the centre of convex base having six holes connecting to six compartments. Therefore, whatever milk was poured in this circular compartment, it was being distributed almost equally to six segments which were provided with nipples. This facility has further decreased the man-power requirement compared to earlier model in which one has to pour 250 ml milk six times while filling the six compartments. In the refined model, it was possible to pour 1,500 ml milk in one go to central compartment which was automatically distributed to connected six compartments.

Results and Discussion

The designed group milk feeder was tested for its utility for the feeding of milk to kids which was found to be quite effective and man-power saver as compare to bottle milk feeder. In the group of kids which naturally suckled their mothers, there was no involvement of labourer as they suckled as and when they desired. **Table 1** represents the labour requirement in milk feeding operations at different stage of age. In bottle feeding group, the man-minute required for milk feeding operations of a single kid during first 15 days of life ranged from 2.31 to 2.43 minutes during morning/ evening sessions. However, after 15 days, man-minute required reduced greatly from 1.16 to 1.58. The decrease in man minute requirement was due to learnt experience by the kids. The similar trend of bottle feeding was also observed in GMF. The average man-minute in GMF ranged from 0.88 to 0.92 minute in first 15 days which was subsequently reduced to 0.475 to 0.420 minutes in rest part of experiment extended up to 90 days.

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Fig. 1 Group Milk Feeder

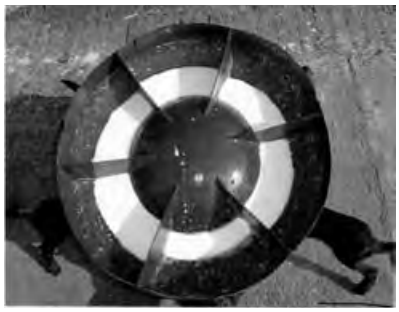

Fig. 2 Group Milk Feeder with kids in action

Fig. 3 Refined Group Milk Feeder

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Development and Evaluation of Power Tiller Operated Zero Till-Drill for Mechanizing Wheat Sowing in Hills

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Abstract

In hills, the soil resource has suffered from degradation particularly due to improper terraces and sloppy land as well as excessive soil tilling with bullock operated soil stirring plough as well as tractor operated disc plough and cultivator. To counter the effects of soil degradation caused by excessive tillage of the soil, one must find and adopt new methods of sowing particularly in annual cropping of wheat. Under zero-tillage, crops are planted with minimum disturbance of soil by placing the seeds in a narrow slits 3-4 cm wide and 4-7 cm deep without land preparation. Number of zero till drills have been developed in India but due to bulkiness, it is not feasible to operate as such in hills. Hence, there is a need to develop and evaluate the power tiller operated zero till drill suitable for hill agriculture.

Therefore, a prototype of power tiller operated zero till drill was developed and fabricated for sowing wheat crop with main design consideration i.e. light in weight and easy turning of zero till drill with power tiller in small terraces. The field performance of machine was carried out at University farm and farmers' fields for three consecutive years. The wheat crop was sown at an average moisture content of about 22.80 %. The effective field capacity was observed to be 0.10 ha/h at a forward speed of 2.2 km/h with field efficiency 60 %. The cost of operation with zero-till drill was Rs. 1,475 /ha ($ 22.00 /ha) which was 65 % lower as compared to traditional method. The yield was observed to be the same as compared to traditional methods of sowing. Zero-tillage seeding also offers the benefits of retained surface residues and reduced soil water losses. Zero-tillage allows early and timely sowing of wheat crop and reduces the cost of production through lesser use of fossil fuels and herbicides etc.

Introduction

Zero-tillage planting of wheat after rice has been the most successful resource-conserving technology to date in the Indo-Gangetic Plains, particularly in northwest India and to a lesser extent the Indus plains in Pakistan (Erenstein *et al.*, 2007; Erenstein and Laxmi, 2008). The interest in zero-tillage in the Indo-Gangetic Plains originated from diagnostic studies that highlighted the importance of time conflicts between rice harvesting and wheat planting in both northwest India (Fujisaka, Harrington, and Hobbs 1994; Harrington *et al*., 1993). The prevailing zero-tillage technology in rice-wheat systems in the area is use of a tractor-drawn seed drill with 6 to 11 inverted-T tines to seed wheat directly into unplowed fields with a single pass of the tractor. Zero-tillage, the direct seeding of wheat into un-ploughed paddies following rice harvest, offers a more sustainable alternative. It involves a single tractor pass, thereby saving fuel, cutting greenhouse gas emissions, and allowing the earlier planting of wheat.

In hills of Himachal Pradesh of India, the farming is practiced in terraces and sloppy land. The soil resource has suffered from degradation over the past many years. The major contributor to this trend in soil organic matter loss is tilling of soil with bullock soil stirring plough as well as tractor drawn disc plough and cultivator in preparing the land for seeding (Vatsa and Singh 2010). To counter the effects of soil degradation caused by excessive tillage

of the soil, one must find and adopt new methods of sowing wheat in annual cropping. Presently the wheat is major crop grown in an area of 367 thousand hectare out of net area sown of 508 thousand hectare in this hill region (Anonymous, 2010). Under zero-tillage, crops are planted with minimum disturbance of soil by placing the seeds in a narrow slit 3-4 cm wide and 4-7 cm deep without land preparation. Zero-tillage seeding offers the benefits of retained surface residues and reduced soil water losses. By increasing soil water (the limiting crop production factor in un-irrigated farming) through better retention of snow and rainfall, and decreasing evaporation losses, the yield can be increased. Zero-tillage allows early and timely sowing of wheat crop and reduces the cost of production through lesser use of fossil fuels and herbicides etc. There are fewer weeds, because the soil is not disturbed in the zero-tillage systems. In addition, there is significant increases in profit as costs of production are reduced. Zero-tillage cultivation is a farming practice that reduces costs while maintaining harvests and protecting the environment. Numbers of zero till drill have been developed by the centres but due to bulkiness, it is not feasible to operate these as such in hills. Hence, there is a need to develop and evaluate the power tiller operated zero till drill.

Table 1 The specifications of the machine

Parameters	Value
Overall dimensions	
Length, mm	775
Width, mm	770
Height, mm	790
Total weight, kg	49
Power source	Power tiller (10-15hp)
Number of row	3
Row spacing, mm	220
Depth of sowing	Adjustable up to 100 mm
Seed and fertilizer metering device	Fluted roller made of aluminium
Power transmission to metering device	From ground wheel through sprocket and chain arrangement

Methodology

Design Considerations

The zero till drill was developed with following design parameters:

1. The machine should be light in weight i.e. less than 50 kg.
2. The machine should be suitable for operation with power tiller in small terraces.
3. It should sow wheat in three rows at a time.
4. The turning radius of the machine should be minimum possible.
5. The machine should reduce cost of sowing and labour requirement.
6. The sowing could be done at desired depth by adjusting the furrow opener.
7. The design of the digger should be simple so that small and local manufacturer could easily fabricate.
8. The machine should disturb soil as minimum as possible to protect the soil degradation in hills.
9. The care and maintenance costs should be low.
10. The cost of machine should be within the purchasing power of small and medium farmers.

Keeping in view the above design parameters, a prototype of power tiller operated zero till drill was designed and developed for sowing wheat crop. The major specifications of the machine are given in **Table 1**. Conceptual drawing of zero till drill is shown in **Fig. 1**.

The major components of the zero-till drill are:

1. Frame
2. Slit/furrow openers
3. Seed and fertilizer boxes
1. Seed metering device
4. Fertilizer metering device
5. Power transmission unit
6. Hitch

Field Testing Procedure

The field performance of zero-till drill was carried out at elevation of 1,200-1,300 m amsl in a small plots. The machine was tested for three consecutive years (2009-11) by attaching it to a 13 hp Mitsubishi power tiller. The machine and field performance parameters such as depth of sowing, field capacity, field efficiency, labour requirement, fuel consumption, seed and fertilizer rate etc. were taken. The recom-

Fig. 1 Drawing of power tiller operated zero till drill

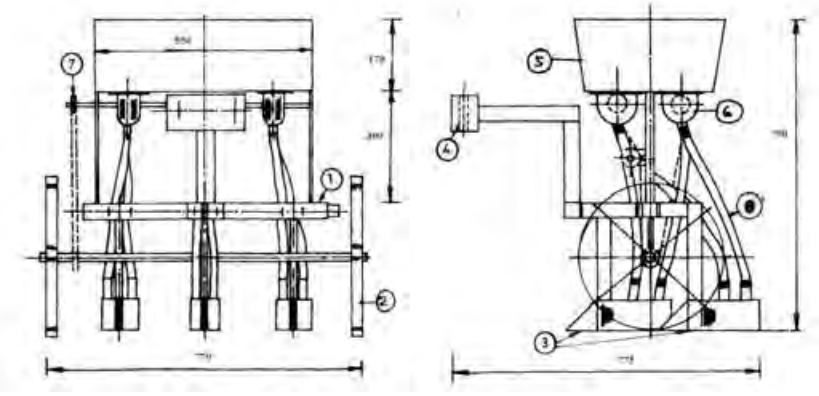

Table 2 Recommended practices for wheat crop

Parameters	Wheat
Seed rate, Kg/ha	120
Fertilizer, NPK doses per ha	120: 60: 30
Row spacing, mm	225
Seed spacing, mm	Continuous

mended practices for wheat crop are given below in **Table 2**.

Cost Analysis

The cost calculation was also carried in accordance with the procedure given in the IS code. The durations for which the power tiller and zero till drill were operated in a year were assumed to be 800 and 200 hours, respectively. The fixed and variable costs associated with the power tiller and the zero till drill were considered while calculating the sowing cost.

Results and Discussion

Development and Construction Details of Zero-Till Drill

The development of power tiller operated zero-till drill was carried out in the agricultural engineering workshop (**Fig. 2**) at CSK Himachal Pradesh Agricultural University, Palampur. The rectangular main frame 620 × 240 mm was fabricated by using 40 × 40 × 5 mm size mild steel angle iron. With a vertical height of 300 mm on the top of the frame, a rectangular seed hopper of size 550 × 405 mm fabricated from M.S. sheet of 22 gauge fitted with the help of nuts and bolts. The opening was provided in the lower portion of the hopper for fitting the metering rollers for seed and fertilizers. The aluminum fluted rollers were mounted with the help of pins on 16 mm mild steel shaft supported on both ends by M.S. bushes.

On one side of the shaft, sprocket was fitted with the help of sliding key for metering the roller. The drive to the metering rollers was provided through chain and sprocket arrangement from the ground wheels. Wheel size of 330 mm diameter made of 35 × 3 mm flat mounted on a 20 mm mild steel shaft supported on both ends by 40 mm M.S. bushes of length 60 mm. The 430 mm hitch length was provided made of 40 × 40 × 5 mm size mild steel angle iron with hitch bracket of size 165 × 85 mm made of 5 mm plate. The zero-till drill has three inverted T-type slit/furrow openers. These can be spaced as needed for different crops. These T-type slit/furrow openers when attached to a tine open a narrow slit 3-5 cm wide. The slit/furrow openers provided in zero-till drill were spaced 22.5 cm apart. The cutting portion of the slit/furrow openers is made by using 8 mm thick high carbon bit welded to a mild steel plate. The working front edge of the slit/furrow openers has a piece of carbon steel welded all round the nose, tip and sides to reduce wear and tear. In some drills, manufacturers have provided chisel type slit/furrow openers. The rake angle was kept 20 degrees in order to make a narrow slit with minimum of soil disturbance. The relief/clearance angle of the slit/furrow openers was kept at 5 degrees. The weight of the machine was 49 kg without seed and fertilizer.

Performance of Zero-till drill

The calibration was carried out in the laboratory for metering seed and fertilizer. The field performance of machine was carried out in the paddy harvested field having about 60 cm stubble (**Fig. 3**) at university farm as well as farmers' fields. The machine is very compact and it could be easily operated in small terraces. There is no additional turning radius required for zero till drill with power tiller. The wheat crop was sown at moisture content of 21.60-22.80 % (**Table 3**) for three consecutive years. The effective field capacity was observed to be 0.09-0.10 ha/h at a forward speed of 2.1-2.2 km/h with field efficiency 56-62 %. The labour requirement could be saved more than 50 % with zero till drill. The fuel consumption was 1 L/h with power tiller zero till drill. The yield was found 2.2.5 and 2.18 t/ha with zero till drill from university farm and farmers field, respectively which was little higher as compared to traditional method but there was no significant difference in the yield. The cost of operation with zero-till drill was 60-63

Fig. 2 Power tiller operated zero-till drill

Fig. 3 Testing of zero-till drill

% lower as compared to traditional method. The performance of crop sown by the machine is shown in the **Fig. 4**.

Conclusions

The following conclusions could be drawn from the study:

Three rows power tiller operated zero-till drill was developed for mechanizing sowing operation in hill farming.

The effective field capacity was observed to be 0.09-0.10 ha/h at a forward speed of 2.1-2.2 km/h with field efficiency 56-62 %.

The cost of operation with zero-till drill was 60-63 % lower as compared to traditional method.

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Fig. 4 Crop sown with power tiller zero-till drill

Table 3 Comparative performance of zero till drill

Parameters	Zero-till drill		Traditional method
	University farm	Farmers' field	
Soil moisture content, %	22.80	21.60	18.5
Bulk density, g/cc	1.52	1.47	1.38
Stubble height, mm	50-70	58-65	-
Speed of operation, km/h	2.2	2.1	2.0
Depth of seeding, mm	40-60	45-55	-
Row spacing, mm	220	220	-
Actual seed rate, kg/ha	123.5	122.8	150
Fertilizer rate, kg/ha	277.5	276.6	250
Fuel consumption, l/h	1.0	1.0	-
Effective field capacity, ha/h	0.10	0.09	0.025
Field efficiency, %	62.5	56.2	55.8
Labour requirement, man-h/ha	20	22	46
Cost of operation, Rs/ha	1,680	1,670	3,760
Yield, t/ha	2.25	2.18	2.14

EVENT CALENDAR

◆ ADAGENG 2014
—12th International Congress on Mechanization & Energy in Agriculture—
September 3-6, 2014, Cappadocia, TURKEY
http://www.adageng2014.com/

◆ 4th ISEBE International Symposium on Environmental Biotechnology and Engineering
September 9-12, 2014, Mexico City, MEXICO
http://isebe.cinvestav.mx/

◆ 18th World Congress of CIGR
—International Commission of Agricultural and Biosystems Engineering—
September 9-12, 2014, Beijing, CHINA
http://www.cigr2014.org

◆ 22nd ICID Congress and 65th IEC Meeting
September 14-16, 2014, KwangJu, KOREA
http://www.icid.org/conf_congress.html

◆ 18th International Conference on Information Systems for Agriculture and Forestry
September 15-17, 2014, Jelgava, LATVIA
http://isaf2014.info/

◆ AFITA 2014
—9th Conference of the Asian Federation for Information Technology in Agriculture—
September 29 - October 2, 2014, Perth, AUSTRALIA
http://asicta.org/AFITA2014/

◆ Agro Tech Russia 2014
October 3-6, 2014, Moscow, RUSSIA
http://www.dlg-international.com/392.html

◆ XI Latin American and Caribbean Congress of Agricultural Engineering 2014
October 6-10, 2014, Cancun, MEXICO
http://chapingo.mx/dima/clia2014/
The XI Latin American and Caribbean Congress of Agricultural Engineering (CLIA) 2014 will be held in Cancun, Mexico, from October 6th to 10th, 2014. This focuses on agricultural and biological engineering in area of agriculture, livestock and forestry to improve life of farmers and food producers, with sustainable systems and to protect environment.

◆ ISB-INMA TEH 2014 Agricultural and Mechanical Engineering
—International Symposium—
October 30-31, 2014, Bucharest, Romania, ITALY
http://www.inma.ro/symposia/ISB-INMATEH-2014

◆ EIMA International 2014
November 12-16, 2014, Bologna, ITALY
http://www.eima.it/en/index.php
EIMA Green is participating at EIMA International 2014. EIMA Green, an area devoted to agricultural mechanization, focuses on new technologies and equipment for gardening and plant care and will feature the maintenance of parks and garden architecture at the pavilion. The European market for gardening and groundskeeping machines is returning to substantial sales after the 2008-2009 economic crises. Approximately 15 million units of mowers, brush cutters, garden tractors and other equipment were sold, particularly in the United Kingdom accounting for one quarter of mower sales, a gain of 0.6 % over 2012. Italy still shows negative indication of sales, 1.6 % decrease since the previous year, but there are hopes for a positive trend in 2014.

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

◆ 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

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

◆ 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

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(Vol.43, No.3, Summer, 2012-)

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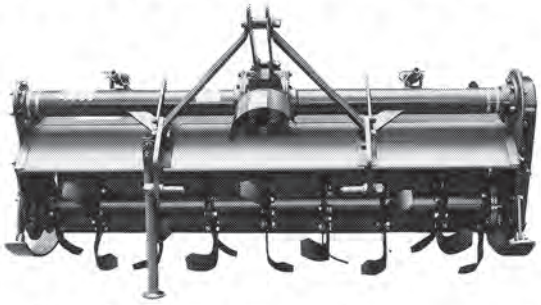

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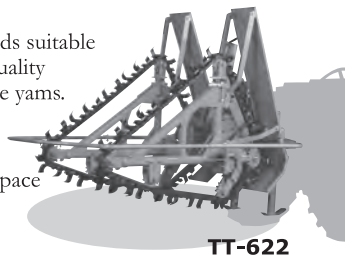

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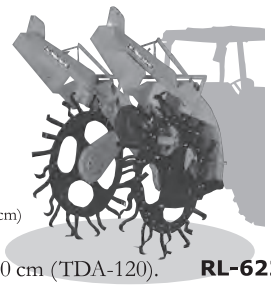

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