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EDITORIAL

It was recently reported that people in South Sudan suffered food shortage. That the civil war prevented farmers from doing their works and it led to serious situation of lack of food and then millions people faced famine. Civil wars cause severe damage to agriculture in Afghanistan, Syria, Iraq, etc. We, those who are engaged in agricultural mechanization, have a mission to resolve the food problem. However, our struggle is severely impaired by civil wars.

Why human beings go to war again and again? When I was ten years old, my father told me what the word BUSHI meant. Bushi is a person who can wield power justifiably. One should use power rightly for a good cause. It is those who can do it that we call them Bushi. Nowadays, science and technology develops incrementally and it's giving humans more and more power. We have to use this power correctly.

The population of us human beings has already reached over 7.3 billion and it continues to increase. Specialists estimate that the number will grow to over 9 or 9.5 billion by 2050. It means there will be two billion more people than now. Can we secure enough food from limited resources in such difficult situations? That's the most difficult challenge for us. We, those who're engaged in agriculture or agricultural machinery, are looking for solutions to it.

One of the most notable increase is in the population of urban areas. Young people choose other than agriculture as their occupation all over the world. It's because trading conditions between agriculture and non-agriculture are unfavorable for agriculture. Therefore, when one is on the side of agriculture, he cannot generate enough profit. It leads to young people's shift to non-agriculture. That causes the increase in the population of urban areas.

We face two challenges. The one is how to increase the amount of food regardless of limited farmlands. It also requires sustainability. The other one is how to fulfill the demand for food regardless of decreasing farmers. The most important thing to resolve these issues is agricultural mechanization. As I mentioned before, timely and precise operation is essential to increase the yield of a crop per unit area. Agricultural mechanization is essential to increase the yield of a crop per unit area. It can be said that agricultural machinery is very important to resolve the issues related to world population and food in this century.

We must promote agricultural mechanization in such a way as it could be suitable for each area, crop and soil condition. To do so, a lot of cooperation is required. Namely, the cooperation is essential between governments, universities, research facilities, manufacturers, dealers, etc. Great cooperation can direct us toward robust way to success and promote agricultural mechanization properly. Communication between keypersons in each field is highly essential. AMA has played the role in facilitating it for 46 years. There're differences in the level of agricultural mechanization among countries. It requires agricultural mechanization in accordance with their level of development.

Totally new technological innovations are coming. This will robotize agriculture using ICT (Information and Communication Technology) and AI (artificial intelligence). The new agricultural machinery will take a form of an agricultural robot from now on. Easy-to-use agricultural robots must spread as rapidly as smart phones did in developing countries. It will be the development of ICT and AI that new agricultural mechanization would depend on.

Yoshisuke Kishida
Chief Editor

July, 2017

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Design, Development and Evaluation of Whole Cane Combine Harvester

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Abstract

This study was undertaken to design, develop and evaluate a tractor operated whole cane combine harvester. The developed unit consists of different sub-systems such as de-topper, crop dividers, knock-down roller, base cutter and de-trasher cum conveyer. The prototype was mounted to a 75 hp four wheel drive tractor and evaluated in field. The required minimum rotary speed of the tractor engine at which all the flow requirement were satisfied and the best combinations of the pumps and motors were finalized by optimization using LINGO software. Field capacity of the developed machine was 0.09 ha h^{-1} with a field efficiency of 75%. Considering the sugarcane average productivity of 50 t ha^{-1}, the cost of harvesting per tonne is Rs. 212 for the developed tractor operated whole cane combine harvester. The tractor operated whole cane combine harvester results in an average savings of 62 and 42% against manual harvesting and self-propelled combine harvesting, respectively. The breakeven point of the developed tractor operated whole cane combine harvester was 694 hours or 63 ha in a year.

Introduction

Sugarcane, *Saccharumofficinarum L.*, one of the most important commercial crops of India, is a renewable, natural agricultural resource providing sugar and bio-fuel besides by-products like, fibre and fertilizer. Sugarcane juice is used for making white sugar, brown sugar, jaggery and ethanol. The main by-products of sugar industry are bagasse (being used as raw material in the paper industry) and molasses, the chief by-product, is the main raw material for alcohol and alcohol-based industries. Manual harvesting of sugarcane is one of the labour intensive (1,200-1,500 human h ha^{-1}) operations responsible for increase in sugarcane production cost (Yadav, 2003). Harvesting involves base cutting, de-trashing, de-topping, bundle making, loading and transport. Hence, mechanization of sugarcane harvesting is considered as an alternative not only to solve the problem of labour shortage but also to reduce the cost of production.

Sharma and Singh (1980) developed a tractor rear mounted harvester operated by a 35 hp tractor and drive was taken from tractor PTO shaft. It consisted of a single row cutting unit comprising of main frame, bevel gear unit to give drive to base cutter, base disc, pusher guards to lift the lodged crop and gauge wheels for adjusting the height of cut and balancing the equipment during operation. Meyer (1997) reported that the cutting operation could be mechanized by using relatively simple cutting attachments mounted on standard tractors or self propelled machines. These cutting aids either deposited the cane in windrows at right angles to the row direction or left the cane in linear windrows parallel to the row direction. Yadav (2003) reported that MPKV Pune developed a tractor front mounted sugarcane harvester. The unit was operated by a 35 hp tractor and power was transmitted through a gearbox to base cutting unit which rotated at 1,500 -2,000 rpm. Cutting operation was performed by saw tooth type cutting disc of the base cutting unit. The gathering and lifter assembly was provided in front of the machine to guide the cane crop for cutting and keeping it erect. Yadav (2008) studied harvesting knives of different sizes, shapes and weights used for sugarcane harvesting at different places in different parts of India.

Indian Institute of Sugarcane Research (2010) developed a tractor-operated sugarcane de-trasher which was powered through a tractor PTO drive. The de-trasher consisted of mechanisms for cane feeding, de-trashing and delivery.

Presently available mechanical harvesters in India are of high capacity and require huge capital investment. Moreover, there is a limitation in operation of mechanical harvesters in small, irregular and fragmented holdings, diversified cropping patterns, limited resource capacity of small and marginal farmers, the peculiar Indian farms. Hence a tractor mounted low cost whole stalk sugarcane harvester will find wide acceptance. Lifting of the lodged cane, de-topping, base cutting, conveying, de-trashing and collecting the canes are the different unit operations to be achieved by a whole stalk sugarcane harvester. Keeping the above factors in view, a tractor operated whole cane combine harvester was designed, developed and evaluated.

Materials and Methods

A sugarcane harvester matching to 75 hp tractor, attachable to the tractor's three point link and powered by the PTO drive, to operate in sugarcane crop row spacing of 900 mm or more was developed at Tamil Nadu Agricultural University, Coimbatore in India. It had provisions for de-topping, conveying of cut canes and de-trashing, provisions for varying the depth of cutting, height of de-topping and level of lifting auger to suit the varying field and crop conditions. The conceptual design and details of components of developed whole cane combine harvester are given below.

a. Conceptual Design of Whole Cane Combine Harvester

Prototype was designed to operate in crops having row spacing of 900 mm or more. The prototype was attached to a hydraulic power pack and mounted by tractor three point linkage system and powered by tractor PTO drive.

b. Components of the Whole Cane Combine Harvester

The whole cane combine harvester consisted of different subsystems such as de-topper, crop dividers, knock-down roller, base cutter, de-trasher cum conveyer and power pack.

Hydraulic Power Pack

The hydraulic power pack is the major unit which provides the required fluid flow rate and pressure. It consists of a reservoir, hydraulic pumps, control valves, hydraulic system analyzer and the frame.

Reservoir system

The reservoir serves as storage space and principal location where the hydraulic fluid is conditioned. It was made with steel plates of 3 mm thickness with overall size of 1100 × 400 × 750 mm sufficient to accommodate 300 litres of hydraulic fluid.

Hydraulic pumps

Two pumps were used for the hydraulic power pack, viz. a main pump and a tandem pump. The main pump is a bent-axis pump (Bosch Rexroth: A2FO series). The second pump is a tandem pump (Bosch-Rexroth: F-N series with 032/014), which consists of a dual pump with two external gear mounted to a single shaft.

Control valves

The hydraulic power pack has directional control valves and flow control valves. Directional control valves are used for operating the hydraulic motors and for lifting and lowering the hydraulic cylinders. The flow control valves are fitted on the return lines of the motors and cylinders and are separate valve blocks for main pump and tandem pump lines. In addition to these control valves, two pressure relief valves are also fitted on the top of hydraulic reservoir.

The Flo-Check USB Hydraulic System Analyzer was used as a stationary or portable tester for diagnostics, and analysis of the prognostic health of the hydraulic system. It measures flow, pressure, temperature and power simultaneously within a hydraulic system. This module records the operating parameters of the system and transfers them to the user's laptop. The Flo-Check Analyzer software provides a real-time graphical and digital interface for monitoring and/or recording temperature, pressure, and flow rate parameters from the Hydraulic Analyzer.

Frame

The frame for fixing the hydraulic power pack and power drive unit is the main structure of the hydraulic power pack. It is attached to the tractor's three point link and receives PTO power from the tractor.

Harvester Frame

The sugarcane combine harvester frame has provision to attach different sub-system of a combine harvester and at the same time it can be mounted to the main frame of the hydraulic power pack. By this provision, the total harvester is attached to the three point linkage system of the tractor. The overall dimensions of the frame are 1470 × 125 × 1200 mm.

De-topper

The single cut de-topper was designed and developed to retrieve cane top as a feed material for the livestock. It removed the tops from the cane stalk and deposited them evenly simultaneously clearing the row being harvested. The parameters considered for the design of the de-topper were the number of canes cut per unit time which is a function of the number of canes per meter, the forward speed of the machine and the height variation of the sugarcane crop.

The de-topping system consists of a de-topper head and a lifting and lowering mechanism (**Fig. 1**). The system is attached to the base frame of the sugarcane combine on a vertical upstanding post. The total unit can be rotated on the above upstanding post and can be locked in the forward direction during harvesting operation. It can be rotated and kept parallel to the main frame and the hydraulic power pack while transporting.

De-topping head

The de-topping head consists of a crop gathering unit, feeding unit, rotary cutting unit and after-cut deflection unit. The crop gathering unit gathers the canes which are to be de-topped by the cutting unit and feed these canes to the cutting unit and de-top the sugarcane crop. The deflection unit deflects the severed tops from the current cutting row and the tractor operator. Feeding unit and rotary cutting unit are integrated and are powered by a single hydraulic motor, which is mounted to the de-topping head frame. Eight units of 75 mm equilateral triangular shaped serrated blades are attached to the outer circumference of 4 mm circular plate of 430 mm diameter, by rivets. The feeding unit is attached to a 4 mm thick pipe of 250 mm diameter having a length of 250 mm. The feed unit consists of eight feed members which are attached to the above pipe at an off-set of 80 mm from the cutting blades plane. The feeding members are 'V' shaped in cross section and have a length of 100 mm. The feeding unit is attached to the circular plate of the cutting unit and the circular plate is fixed on the drive shaft of the hydraulic motor through a flange coupling. The hydraulic motor is used for rotating the de-topper head and a directional control valve is used to operate the motor.

Lifting and lowering mechanism

It consist of a four bar linkage is made as a parallelogram linkage such that the opposite links are having the same length that keeps the de-topper head always in horizontal level at all positions. The longer horizontal links (1,500 mm) determine the advancement required by the de-topper from the base cutter. One of the smaller vertical link (200 mm) is made as a fixed link and is having provision to attach the de-topper unit to the upstanding post of the harvester base frame. Another vertical link is transformed as the de-topper head frame.

The hydraulic cylinder is provided in the system to raise and lower the de-topping head so as to carry out cane de-topping at a proper height. The required upper and lower level is based on the height variations of the sugarcane and is fixed from 1,500 mm to 2,700 mm. The one end of the hydraulic cylinder is hinged to the top horizontal link and the other to the extended portion of the vertical fixed link. The height of cutting is achieved by lifting or lowering the de-topping head with a directional control valve and the speed of lifting and lowering is controlled by the flow control valve in the output line of hydraulic cylinder.

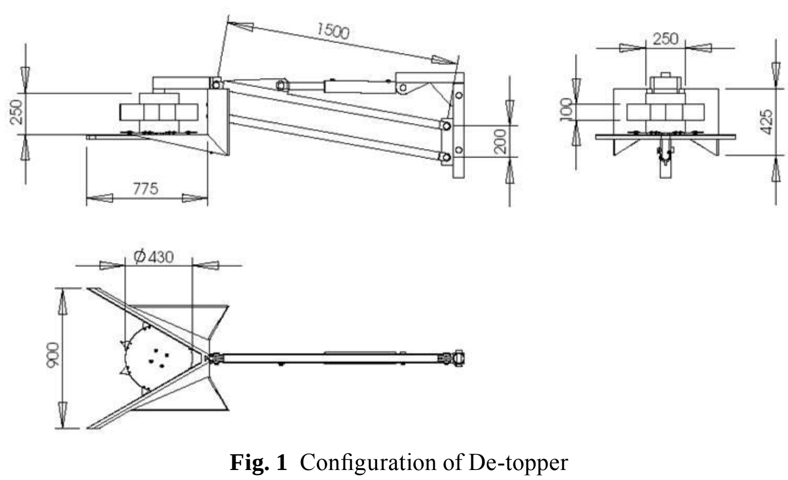

Fig. 1 Configuration of De-topper

Crop Dividers

The main purpose of the crop divider is to release the cane that is entangled with the adjacent row and are provided on both sides of the base cutter, to lift the lodged canes and to gather canes in a row. It consists of rotating auger and a crop divider positioning mechanism.

Auger

The main working part of the crop divider is the augers which are left and right spiral based on the position where it is fitted. The lifting scrolls are made of two mm thick mild steel sheet wrapped in a spiral form around a 60 mm diameter pipe of 1,200 mm length. The diameter of the spiral is tapering towards the bottom from 255 to 120 mm. The top end of the scroll is fitted with a hydraulic motor through flange coupling for providing the rotation to the auger. The bottom portion of the scroll is fitted to a square flanged bearing of 25 mm diameter through a bush and is attached with a curvilinear skid. The view the auger is shown in **Fig. 2**.

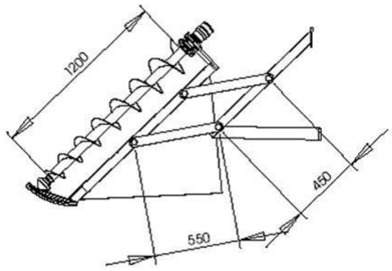

Fig. 2 Configuration of Crop dividers

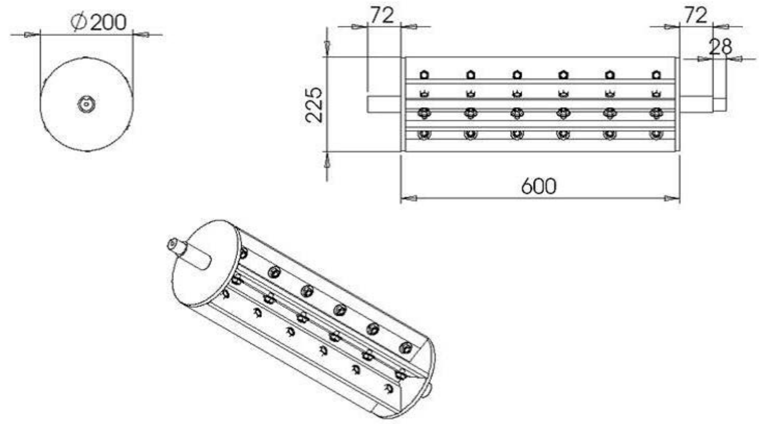

Fig. 3 Configuration of Knock-down roller

An OMP 32 hydraulic motor is used for powering the auger unit. The motor is connected through the directional control valve in the input line for on/off function and to change the direction of rotation. The speed of rotation of hydraulic motor is controlled by the flow control valve provided in the output line.

Crop divider positioning mechanism

It consists of a parallelogram type four-bar linkage system. The links are provided such that the opposite links will be of the same length. This will enable to lift and lower the augers in parallel to the original position. One link is fixed to the main frame of the combine harvester and the opposite link is attached to the auger (**Fig. 2**). The fixed link is attached to the main frame at an angle of 45^o with the vertical and the auger is fixed to the auger link such that it will make 10^o with the horizontal. This is to congregate the crop spread from 900 mm to 600 mm which is the through opening of the input roller. The inner sides of the augers are provided with side plate such that the crop will be converged to the base cutter and then to the input rollers. The side plate is split into two portions such that one will be fixed to the fixed link and the other is fixed to the auger link. The movable side plate moves along with the lift and lower actions of the auger.

The hydraulic cylinder is provided in the system to move up and down the crop divider for adjusting the proper depth of the augers. The one end of the hydraulic cylinder is attached to the top link and the other end to the sugarcane combine harvester base frame using pin hinges. The cylinder is having a stroke of 300 mm and in turn it will raise or lower the auger in a span of 750 mm vertically. The lower end of the span is provided such that, the auger bottom point will move 150 mm below the base cutter blade tip. This is provided to lift the crop which are scattered beyond the bund of the crop. The same configuration is provided for both the augers. The depth is achieved by lifting or lowering the auger through the direction control valve and the speed of lifting and lowering is controlled by the flow control valve in the output line of hydraulic cylinder.

Knock-Down Roller

The knock-down roller is attached to the combine harvester frame, forward to the base cutter. It bents the cane stalk before it is cut by the base cutter to ensure good quality base cut and permit easy capture of cane stalks by input rollers. The knock-down rollers are fixed in such a way that the erected cane bend up to an angle of 30^o before base cutting. The roller is of 600 mm in length and 225 mm in diameter (**Fig. 3**). The rotation of the knock-down roller, along with the forward movement of the machine, moves the canes into the gathering system or throat.

Base Cutter

The base cutter unit is a double cutter for easy conveying of the cut sugarcane stalks. The cutter blades are attached to the base cutter disc. The base cutter disc is mounted on the drive shaft of the base cutter through a conical hub. The conical hub prevents the binding of the trash on the base cutter drive shaft. The diameter of the base cutter disc is 380 mm and the tip-blade diameter is 540 mm (**Fig. 4**). The speed of the disc is set to 550 rpm for getting

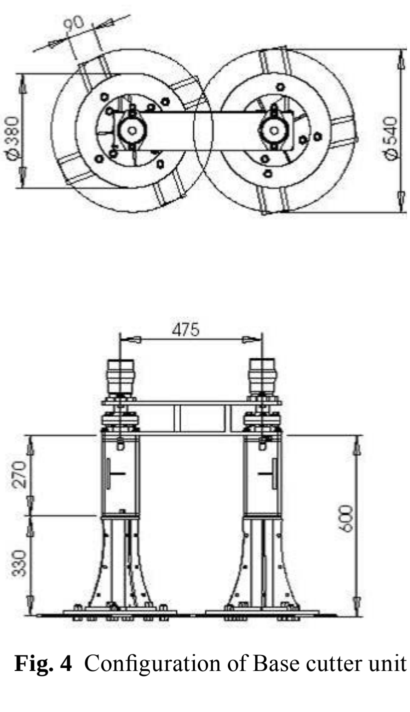

Fig. 4 Configuration of Base cutter unit

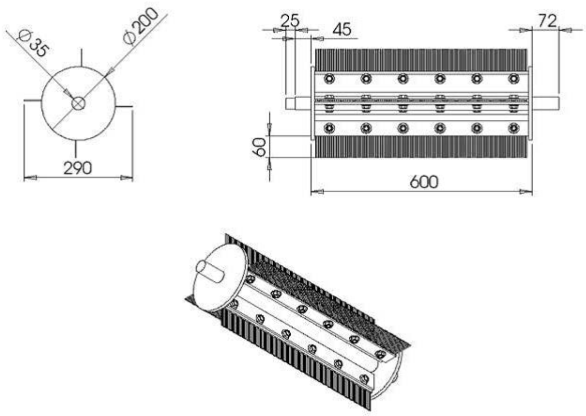

Fig. 5 Configuration of De-trasher roller

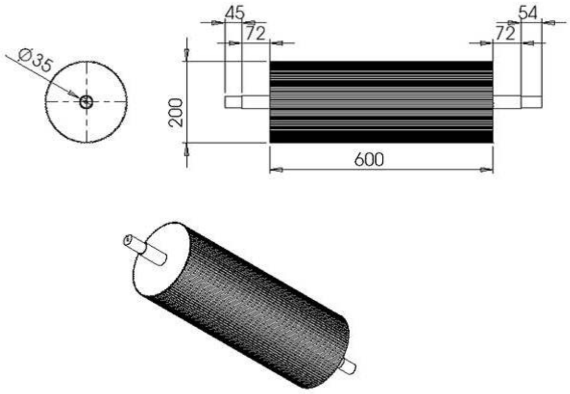

Fig. 6 Configuration of Output roller

peripheral speed of 14 m s^{-1}. The tilt angle of the blades is maintained by providing the required tilt to the base cutter disc and the oblique angles are achieved by fixing arrangement of the blades to the base cutter disc. Thus the blades are mounted at the designed tilt angle and oblique angles of 100 and 300, respectively. The base cutter is powered by two OMP 80 hydraulic motors connected in series.

De-Trasher Cum Conveyer

The de-trasher cum conveyer system is used to remove the adhering cane foliage and to convey the de-trashed canes. The system consists of a guide plate, feed rollers, de-trasher rollers and output rollers.

Guide plate

A guide plate is provided behind the base cutter for guiding the cut cane stalks to the input roller and also to avoid the repeated cutting of the cane by the base cutter blades. This guide plate is fixed to the side plates of the de-trasher cum conveyer unit such that it will not affect the rotation of the base cutter and the cut sugarcanes will not pass in between the base cutter discs and the guide plate.

Feed rollers

Two pairs of counter rotating feed rollers are provided for feeding the cut sugarcane stalks into de-trashing system. The second set of roller is rotating at a higher speed than the first set of rollers. The rollers are of 600 mm in length and 280 mm in diameter. The feed rollers are fabricated by welding two flanges of 200 mm diameter to a shaft of 40 mm and in between the flanges 6 flat pieces in axial direction. The first sets of rollers are rotated at a speed of 200 rpm. The chain and sprockets are provided in such a way that the second rollers will rotate at 12 percent higher speed than the first. The power is given to the first set of rollers by means of hydraulic motors (OMP 50 motor) and the same is transferred to the second roller through sprocket and chain arrangements.

De-trasher rollers

The de-trasher system consists of a set of nylon wire brush rollers, rotated in opposite direction. The effective length of the roller is 600 mm and the diameter is 290 mm (**Fig. 5**). The power for the same is provided with a hydraulic motor (OMP 50 motor). The power is transferred to the counter rotating de-trasher rollers through a step up gear box. The direction of rotation of the de-trasher roller is the same as the input rollers. Hence it acts in the same direction of the cane movement. The one end of the de-trasher roller shaft is attached to the gear box and the other end is fixed to the side plate through a flange type pillow block bearing.

Output rollers

The output rollers are hollow cylindrical drums with a length of 600 mm and diameter of 200 mm and the outer surfaces are covered with corrugated rubber sheets for grip. They impart a pull to the de-trashed canes (**Fig. 6**). Two sets of counter rotating rollers are provided as the output rollers. The power is transferred to the other rollers by chain and sprocket arrangement. All the rollers are rotating at the same speed. In each counter rotating roller, one is fixed and the other is swivelled. Tension springs are provided to the swilled rollers to provide sufficient grip on the sugarcane for getting a positive drive. All the roller shafts are mounted with flange type pillow block bearing and the blocks in turn fixed to both side plates. The hydraulic motor for the out-put rollers is an OMP 32 motor.

c. Field Evaluation

The developed whole cane harvester was evaluated at farmers' fields at Modachur and Pudhukaripattu villages of Gobichettipalayam taluk in Erode district of Tamil Nadu. The de-topping, base cutting, de-trashing and conveying performance of the machine are evaluated in the field.

Results and Discussions

a. Functional Design of Tractor

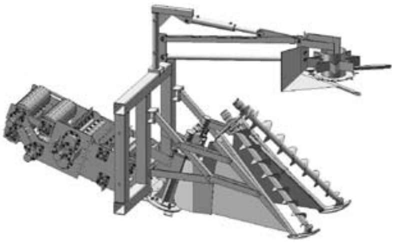

Fig. 7 Isometric view of Solid-works model tractor operated whole cane comvine harvester

Plate 1 Front view of tractor operated whole cane comvine harvester

Plate 2 Isomertic view of tractor operated whole cane comvine harvester

Operated Whole Cane Combine Harvester

Based on the functional requirements, the tractor operated whole cane combine harvester was designed, developed and evaluated. It consists of different sub systems such as de-topper, crop dividers, knock-down roller, base cutter and de-trasher cum conveyer. **Fig. 7** shows the solid work model of the harvester. The developed prototype of the tractor operated sugarcane combine harvester with it all components is shown in **Plate 1** and **Plate 2**.

b. Laboratory Tests

The de-trashing and conveying performance of the machine was evaluated at stationary condition. The cut canes were feed into the input rollers and the performance of the conveyer and de-trasher were ascertained. For accommodating more sugarcane stalks, alternate tyre carcase of the top input rollers were removed. The de-trashing of the cane was excellent and an efficiency of 98% was recorded in the laboratory tests. Fuel consumption of tractor during the test was 3.5 L h^{-1}.

The tractor operated whole cane combine harvester was evaluated at no load for stability, speed and slip in laboratory under working conditions. Wheel slip of the tractor operated sugarcane combine harvester was measured on road and in sugarcane field. The wheel slip was found to be 3.5% on road and 16% under

Specifications of tractor operated whole cane combine harvester 2-1

Power source		
Model	New Holland 7500 tractor	
Engine	75 hp IVECO, Bharat TREM III	
Hydraulic power pack		
Hydraulic pumps	1	2
Type	Bent axis pump	Tandem pump
Make	Rexroth	Rexroth
Model	A2FO160	AZPNF
Displacement	160 cc rev^{-1}	032/014 cc rev^{-1}
Capacity of the reservoir	300 litres	
Flow control valves	Two bank valve: 1	
	Three bank valve: 1	
	Six bank valve: 1	
Harvester frame		
Dimensions	1465 × 125 × 1200 mm	
De-topper		
Dimensions	2450 × 900 × 675 mm	
Adjustable height	960-3600 mm	
Number of blades	8	
Drive	Hydraulic, reversible	
Crop dividers		
Dimensions	1900 × 1000 × 1200mm	
Number of augers	2	
Inclination of the auger	45 degree	
Maximum lift	750 mm	
Distance between points	900 mm	
Drive	Hydraulic, reversible	
Knock down roller		
Number of rollers	1	
Roller width	600 mm	
Diameter	225 mm	
Drive	Hydraulic, reversible	
Base cutter		
Dimensions	980 × 530 × 850 mm	
Centre to centre distance	475 mm	
Number of discs.	2, detachable	
Number of blades per disc	4, replaceable	
Drive	Hydraulic, reversible	
De-trasher cum conveyer		
Dimensions	1750 × 800 × 500 mm	

(Continued on next page)

field condition at tractor speeds ranging from 0.5 to 2 km h^{-1}.

c. Field Evaluation

The first field trial was conducted at Modachur and Pudhukaripattu. The field consisted of five feet row spacing crop of CO 86302 variety having a yield of 50-60 t ha^{-1}. The trial was conducted at a speed of one km h^{-1} at low I gear. On the basis of the trials, it was concluded that all the unit operations such as de-topping, base cutting, conveying and de-trashing performed well. It was also observed that the chocking of the input roller occurred if the number of canes in a meter length were more than 30. Hence, the vertical spacing of the de-trasher roller is to be increased. The transmission ratio of the tractor PTO to hydraulic pump is also to be increased for getting more fluid flow even at lower engine rpm of the tractor. The breakeven point of the developed tractor operated whole cane combine harvester was 694 hours or 63 ha in a year.

Conclusions

The field capacity of the machine was 0.09 ha h^{-1} at a field efficiency of 75%. Considering the sugarcane average productivity of 50 t ha^{-1}, the cost of harvesting per tonne is Rs. 212 for the developed tractor operated whole cane combine harvester. Whereas, the manual harvesting and self-propelled combine harvesting rates are Rs. 560 t^{-1} and Rs. 390 t^{-1}, respectively. Hence, the developed tractor operated whole cane combine harvester results in an average savings of 62 and 42% against manual harvesting and self propelled combine harvesting, respectively. The breakeven point of the developed tractor operated whole cane combine harvester was 694 hours or 63 ha in a year.

REFERENCES

Indian Institute of Sugarcane Research. 2010. Annual Report 2009-10. Director, Indian Institute of Sugarcane Research, Lucknow: 47

Meyer, E. 1997. Factors to consider when implementing a fully mechanised sugarcane harvesting system. Proceedings of the South African Sugar Technologists' Association 71: 79-81.

Sharma, M. P. and K. Singh. 1980. IISR tractor mounted sugarcane harvester. The Indian sugar crops J. 7: 95-98.

Yadav, R. N. S. 2003. Sugarcane Production Machinery. A bulletin published by CIAE Bhopal under NATP on Sugarcane Mechanization: 34-43.

Yadav, R. N. S. 2008. Mechanization of sugarcane production in India, Sugar Cane International. 26(2): 12-17.

■■

Specifications of tractor operated whole cane combine harvester 2-2

(Continued from the previous page)

Feed rollers	
Number of rollers	2 pair
Roller width	600 mm
Diameter	280 mm
Drive	Hydraulic, reversible
De-trasher rollers	
Number of rollers	1 pair
Roller width	600 mm
Diameter	290 mm
Drive	Hydraulic, reversible
De-trasher type	Brush type
Output rollers	
Number of rollers	2 pair
Roller width	600 mm
Diameter	200 mm
Drive	Hydraulic, reversible

Detaching of Saffron Flower Parts Based on Aerodynamic Properties

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Abstract

Saffron crocus, Crocus sativus, a bulbous perennial of the iris family (Iridaceae) treasured for its golden-color, pungent stigmas which are dried and used to flavor and color foods as a dyer. Saffron harvesting is traditionally carried out by hands and it consequently has increased the saffron's production cost. The aim of this study is to study and develop an automotive machine to separate stigma from the other parts of saffron flower to increase the level of automation and efficiency of the post-harvest operations. A prototype separator was designed based on saffron aerodynamic properties in order to study the effect of air flow speed on the saffron separation. According to the experiments result, 100% of petals drive out from the outlet D and 63% of stigma and anther can be separated. Meanwhile the maximum number of stigma discharged from outlet B at the air speed of 4 (m/s).

Keywords: Saffron, Stigma, Aerodynamic properties

Introduction

Purple-flowered saffron crocus, Crocus sativus, a bulbous perennial of the iris family (Iridaceae) treasured for its golden-coloured, pungent stigmas, which are dried and used to flavor and colour foods and as a dye [1]. Crocus sativus is an autumn-flowering geophyte which extensively grown in the Mediterranean basin and Near East since the Late Bronze Age [2]. Saffron is cultivated chiefly in Spain, France, Sicily, Italy (on the lower spurs of the Apennines Range), and in Iran, and Kashmir [3]. Iran produces more than 90% of the world's

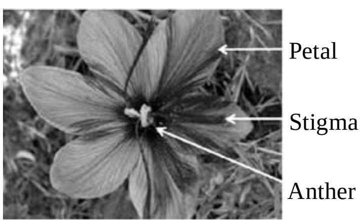

Fig. 1 Parts of saffron flower

Fig. 2 A typical saffron farm

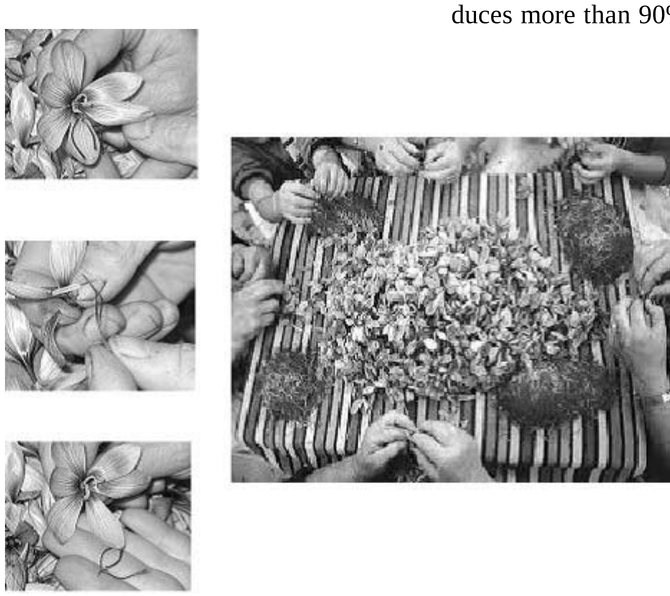

Fig. 3 Traditional method of saffron harvesting

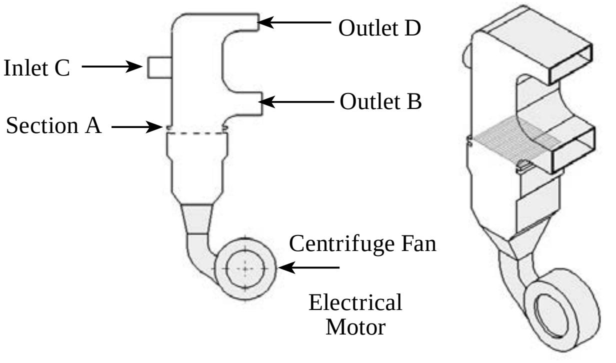

Fig. 4 Schematic representation of the automated saffron separator, inlet and outlets of separator are shown

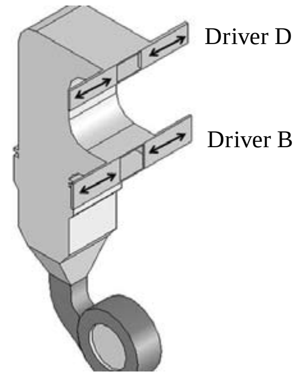

Fig. 5 The position of drivers

Fig. 6 The prototype of saffron separation

total saffron production and more than 92% of Iranian saffron is cultivated in Khorasan province with nearly 210 Tons Annual Production [4]. There is some evidence to suggest that saffron may help alleviate the symptoms of major depressive disorder [5], [6]. Preclinical studies indicate that saffron could be a promising candidate for cancer chemoprevention studies [7]. The stigma, as the only economic part of flower has eatable and medicinal applications [1]. Saffron flower includes three main parts: petal, stigma and anther which are shown in **Fig. 1**. Three stigmas are borne in the center of each purple, cup-shaped bloom. A saffron flower has 3 stigmas which are red in color and their lengths are between 20 and 30 mm, also a flower has at least three petals, which are distinct from one another. The petals lengths are between 30 mm to 46 mm with purple in color. Meanwhile anther color is yellow and its length is around 20 mm [8]. Saffron harvest is crucial milestone for farmers. Saffron crocus blooms in fall, October, over the course of three weeks, when the saffron crocus harvesting commences. The best time to harvest the stigmas is mid-morning on a sunny day when the flowers are fully opened and still fresh as it is shown in **Fig. 2**. Flower harvesting is traditionally carried out by hand. To harvest, labors cut off the open flowers at midmorning on a sunny day. The flowers are piled on a table where labors can work comfortably. Then labors should extract the 3 red filaments from the pistil as shown in **Fig. 3**. This operation is called trimming. Trimming the flowers must be done soon after they are harvested to make the task easier. Meanwhile the yellow stamens and purple petals have no use. For preparing one kilogram of stigma, 78 kg of saffron flowers are required; each kilogram of saffron has approximately 2,170 flowers. And also, The whole operation, trimming a flower and extracting three stigmas, takes about 5 seconds per flower. Therefore, for preparing one kilogram stigma takes 230 hours [9].

Harvesting methods traditionally increase the cost of saffron production, also creates a limitation for farmers who want to extend their farms. Therefore, automatic harvesting of saffron is not only economical, but also urgent. Therefore a lot of efforts have been done to increase the level of automation in saffron harvesting. Aerodynamic properties including terminal velocities of saffron parts are studied, by some researchers [8]. As well as physical properties including shear strength of saffron is studied by other researchers [10]. According to terminal velocities, several wind tunnels are developed to separate saffron particles from impurities. [4]. In a study, researchers has tried to separate saffron parts independently by using airflows to wipe out worthless and unneeded particles; therefore, three models of air separation with several structural differences at duct diameter, air speed and the separation surface are examined [11]. It is reported that saffron components have been separated by using wind tunnel in laboratories [12]. In addition, by using a wind tunnel and fuzzy logic, saffron parts get separated [4]. In a creative method, saffron parts distinguished with image processing method and then separated by using air flow [1]. In a novel study, a mechanical system was designed to harvest Crocus Sativus (saffron) flowers which collect the detached flower through a vacuum collector. The system was operated manually [13]. The aim of this research is to study the effect of different air flow speeds on the function of a saffron separator.

Saffron Separator Details

Saffron parts (stigma, petal, and anther) have different aerodynamic properties. Thus, prototype separator was designed based on saffron aerodynamic properties (terminal velocities). The separator has two main outlets, one of which is for leaving stigma (outlet B) and another for leaving petal (outlet D). Meanwhile, saffron parts feed to the machine from inlet C. It is estimated that the petal will be remain in the section A. The separator drawing is presented in **Fig. 4**. The dimension of outlets presented in **Table 1**. Terminal velocities of saffron parts are different, so for creating different air flow speeds, slider driver is used. Drivers can move and change the area of outlets so that making it possible to change air flow speed in each section of separator independently. Therefore, their positions have significant effect on the separation process (**Fig. 5**). The prototype is made of transparent plexiglass which makes it possible to observe all processes. Because of static electricity, all walls are covered with a layer of aluminum. The prototype separator (**Fig. 6**) which is designed and fabricated in the Agricultural Research Center of Mashhad (Iran) [14] that has been utilized in this study.

Table 1 Dimensions of the separator

Rectangular size (mm)	Section
406 × 406	Section A
406 × 330	Outlet B
406 × 180	Outlet D

Table 2 Experimental levels for each parameter

Parameter	Level	Parameter Quantify
Air speed	3	Low, medium and high level
Time	2	level 1 = 30 second level 2 = 60 second
B driver area	2	Outlet area level 1 = 120 mm^2 Outlet area level 2 = 250mm^2
C driver area	2	Outlet area level 1 = 120 mm^2 Outlet area level 2 = 250mm^2

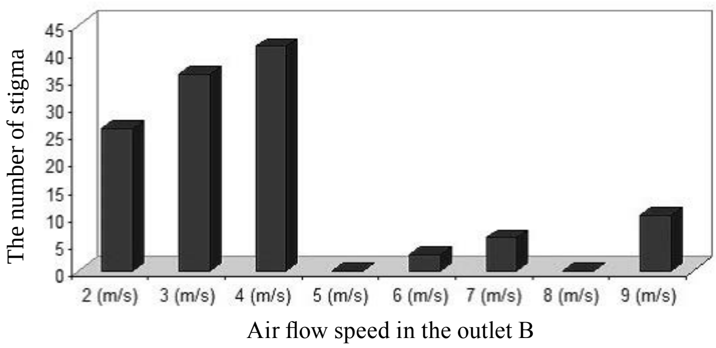

Fig. 7 The relationship between the number of stigma that exit from outlet B and air flow speed in the outlet B

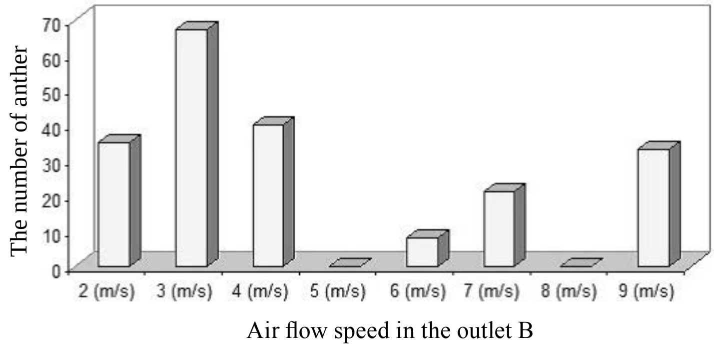

Fig. 8 The relationship between the number of anther that exit from outlet B and air flow speed in the outlet B

Materials and Methods

Experiments are designed according to Design of experiments (DOE) which is a systematic method to determine the relationship between factors affecting a process and the output of that process. Therefore, 24 experiments have been performed. Ten flowers (one batch) are used in every run which 30 stigmas must be ideally separated from the other parts. The variable parameters are air flow speed (3 levels), the area of outlet B (2 levels) and outlet D (2 levels) (D and B driver placed in the two positions; semi open and completely open) and process time (2 levels (30 and 60 seconds)), all details are shown in **Table 2**. Meanwhile the air flow speed is measured with a portable flow meter (Air Flow Meter PCE-007) which has the external impeller with the accuracy of ±3% ±0.1(m/s).

Results and Discussions

The saffron separator is designed to create different air flow in outlet B and D. So, the effect of air flow speed in separating saffron parts in outlet B and outlet D and also in the section A has been studied. The relationship between the numbers of stigma discharged from outlet B and air flow speed is shown in **Fig. 7**. It is clear that the maximum number of stigma discharged when the air flow speed is 4 (m/s). Increasing the speed of airflow from 2 (m/s) to 4 (m/s) lead to rising the number of separated stigma from outlet B. There is a similar pattern for the number of anther which discharged from outlet B as shown in **Fig. 8**. Meanwhile the maximum number of separation has occurred at the speed of 3 (m/s). The relationship between the number of petal which discharged from outlet D and air flow speed in outlet D is shown in **Fig. 9**; and also, the number of petal compared with the number

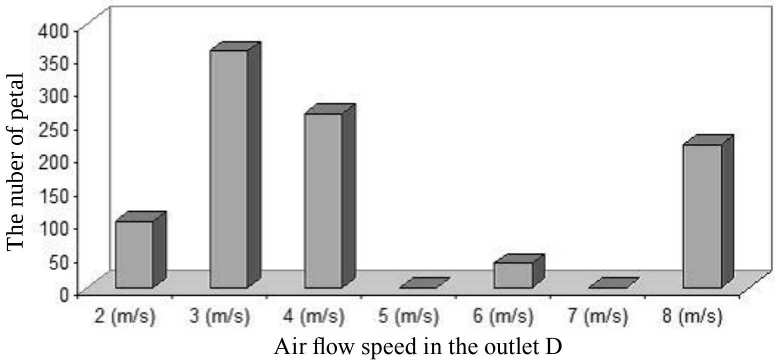

Fig. 9 The relationship between the number of petal that exit from outlet D and air flow speed in the outlet D

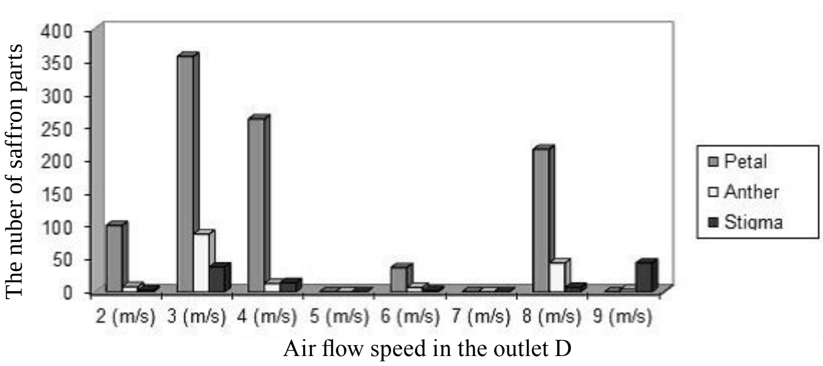

Fig. 10 The relationship between the number of petal, anther and stigma that exit from outlet D and air flow speed in the outlet D

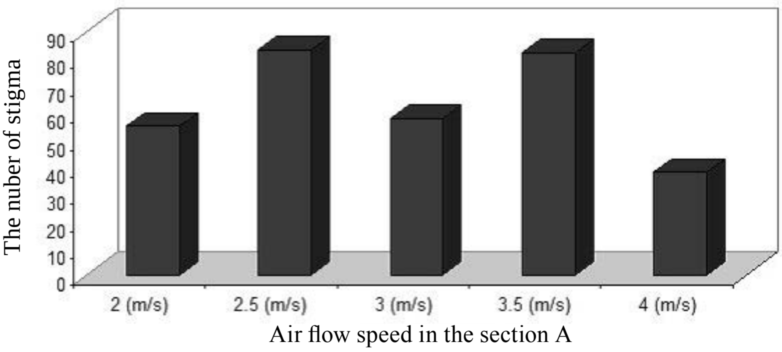

Fig. 11 The relationship between the number of stigma that remain in the section A and air flow speed in the section A

of stigma and anther which leave from outlet D in **Fig. 10**. It is obvious that it is not possible to entirely separate saffron parts from each other completely. The number of stigmas which remain in section A is shown in **Fig. 11** and also the number of anthers and petal which remain in the section A are shown in **Figs. 12** and **13** respectively. It is clear that the saffron parts separate from each other in a wide range of air flow speeds due to the fact that saffron flowers, like all flowers in the nature, are not the same in geometry and weight. The weight of particles should be equal to the drag force which created by air flow, so saffron parts will be floated in the different air flow speed when the weight of saffron flowers are not the same. The **Fig. 14** shows the weight of saffron batch (each batch have 10 flowers). As expected, the weights of batches are not the same. The effect of driver position on the air flow speed in the outlet D is shown in the **Fig. 15**.

A mathematical model is developed to find a suitable approximation for the true functional relationship between the response and the set of independent variables. It is clear that the number of stigma which discharged outlet B and section A is a function of air flow speed in section A, outlet B and outlet D.

The response is modeled by a linear function of the independent variables

$$Y = b_0 + \sum b_i x_i + \varepsilon$$

The final mathematical models are given by:

$$S = 41.6 + 1.83 V_B - 3.94 V_A - 2.72 V_D$$

Using MINITAB 14 statistical

Table 3 The details of estimation of regression coefficients for the number of stigma which discharged outlet B and section A

Predictor	Coef	SE Coef	T	P
Constant	41.628	4.526	9.20	0.000
Vb	1.827	1.293	1.41	0.185
Va	-3.945	1.385	-2.85	0.016
Vd	-2.720	1.427	-1.91	0.083

S = 2.80481, R-Sq = 72.0%, R-Sq (adj) = 64.3%

Table 4 Analysis of Variance for the number of stigma which discharged outlet B and section A

Source	DF	SS	MS	F	P
Regression	3	222.397	74.132	9.42	0.002
Residual Error	11	86.536	7.867		
Total	14	308.933			

software package, the significant coefficients are determined and final models are developed using significant coefficients to estimate the number of stigma leave from the outlet B and remain in the section A. The details of estimation of regression coefficients for the number of stigma which discharged from outlet B and section A is presented in **Table 3** and **Table 4**.

The results of experiments depicts the best separation occurs at the 3-1-2-2 mode (air speed, outlet B and outlet D are high level and time of process is in the low level), that shows wind tunnel was designed perfectly. At this mode, 100% of petals exit from the outlet D as displayed in **Fig. 10**; thus none of them remain at wind tunnel, and 63% of stigmas exit from the outlet B or remain in the section A as illustrated in **Fig. 11**.

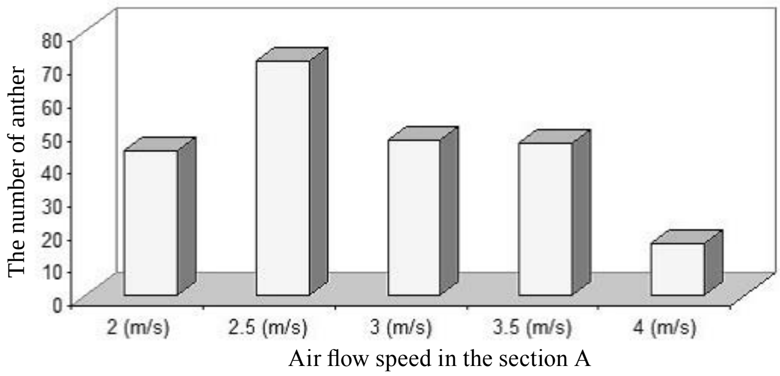

Fig. 12 The relationship between the number of anther that remain in the section A and air flow speed in the section A

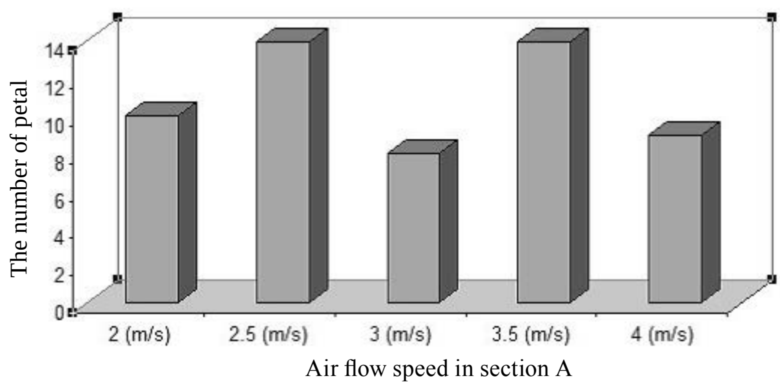

Fig. 13 The relationship between the number of petal that remain in the section A and air flow speed in the section A

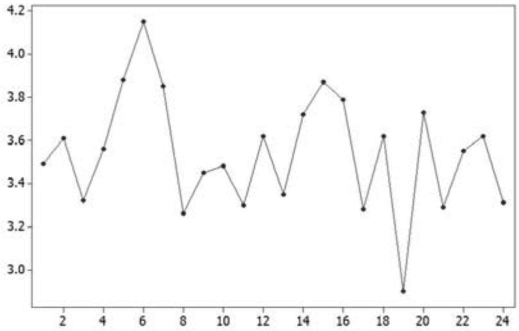

Fig. 14 The relationship between weight of batches and batch numbers

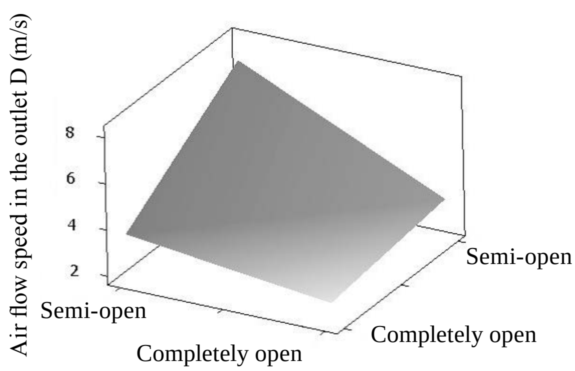

Fig. 15 The relationship between air flow speed in the outlet D and position of outlet B and outlet D

Conclusions

In this study, saffron separator was designed on the basis of aerodynamic and physical properties of saffron flower. The results of experiments show stigma, valuable part of saffron, is separated in a wide range of air flow speeds due to the fact that saffron parts are not the same in shape and weight. However, by using driver flexible area it is possible to find the best conditions for increasing the efficiency of automatic harvesting. The results show that petal is completely separated from other parts and 63% of stigma and anther can be separated. The maximum number of stigma leave from outlet B in the air speed of 4 (m/s) and the maximum number of petal discharged from outlet D in the air speed of 3 (m/s).

REFERENCES

[1] Gracia, L., C. Perez-Vidal and C. Gracia-Lopez. 2009. Automated cutting system to obtain the stigmas of the saffron Flower, biosystems engineering 104, 8-17.

[2] Negbi, M. 1999. Saffron. Crocus sativus L. Harwood Academic Publ. I Overseas Publ. Ass., Amsterdam.

[3] Kafi, M., M. H. Rashed, A. Koocheki and A. Mollafilabi. 2002. Saffron Production Technology and Processing. Center of Excellence for Agronomy (Special Crops). Faculty of Agriculture, Ferdowsi University of Mashhad, Iran.

[4] Alishahi, A. and M. Shamsi. 2012. Separation of saffron components by a vertical wind tunnel and check it with Fuzzy Logic. Journal of Agricultural Machinery. 2 (2) 120-126

[5] Lopresti, A. L., P. D. Drummond. 2014. Saffron (Crocus sativus) for depression: a systematic review of clinical studies and examination of underlying antidepressant mechanisms of action. Human Psychopharmacology: Clinical and Experimental. 29 (6), 517-527.

[6] Hausenblas, H. A., D. Saha, P. J. Dubyak and S. D. Anton. 2013. Saffron (*Crocus sativus* L.) and major depressive disorder: a meta-analysis of randomized clinical trials. Journal of Integrative Medicine. 11 (6), 377-383.

[7] Zhang, Z., C. Z. Wang, X. D. Wen, Y. Shoyama and C. Yuan. 2013. Role of saffron and its constituents on cancer chemoprevention. Pharm Biol. 51 (7), 920-924.

[8] Emadi, B. and M. H. Saiedirad. 2011. Moisture-Dependent Physical Properties of Saffron Flower, J. Agr. Sci. Tech. 13, 387-398.

[9] Emadi, B. 2009. Separating Saffron Flower Parts Using Vertical Air Column, World Academy of Science, Engineering and Technology, 49, 25-28.

[10] Hassan-Beygi, S., H. Vale and J. Khazaei. 2010. Picking force of saffron flower and shear strength of saffron stalk. Electronic Journal of Polish Agricultural Universities, 13:1-9.

[11] Paschino, F. and F. Gambella. 2008. First contribute to the mechanization string of saffron flowers (*Croccus Sativus* L), International Conference: September 15-17.

[12] Shamsi, M., M. Mazloomzadeh, J. Asghari and A. Mohamadian. 2007. using air blowers to separate stigma from saffron flowers. the 3rd national student conference on agricultural machinery and mechanization. Shiraz University, Iran. (In Farsi).

[13] Bertetto, A. M., C. Falchi, R. Pinna and R. Ricciu. 2010. An Integrated Device for Saffron Flowers Detaching and Harvesting, 19th International Workshop on Robotics in Alpe-Adria-Danube Region – RAAD 2010 •June 23-25, 2010, Budapest, Hungary.

[14] Emadi, B. and P. K. D. V. Yarlagadda. 2008. Design of a wind tunnel for separating flower parts of saffron. 9th Global Congress on Manufacturing and management (GCMM2008) 12-14, Holiday Inn, Surface Paradise, Australia.

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Design, Development and Evaluation of Manually Operated Seabuckthorn Fruit Harvesting Tools

by

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Abstract

In Himalayas, about 12,000 ha area is under seabuckthorn having no spacing from plant to plant and row to row as mostly wild/naturally grown and it is distributed widely in the cold arid regions of Himachal Pradesh, Uttaranchal, Ladakh region of Jammu & Kashmir and in some parts of Sikkim. Due to this reason, it is difficult to move in between the plants and introduce particular device/tools for all species. In addition, the fruit is very small and in bunches on the branches having thorn. Hence, the harvesting is performed manually by beating the branches of seabuckthorn with a stick and breaking off the branches from the mother plant on periphery and collecting only 15-20% of the available fruits of the orchards. In this method, a person cannot harvest more than 2 to 3 kg of ripe fruits per hour besides the plant was severely damaged also. For increasing capacity and efficiency, an indigenous manual harvesters i.e. comb, wire clip, branch shaker and clipper with handle type were designed and developed, which is simple in design, light in weight, cost effective and has minimum drudgery, to make the harvesting operation easier and more attractive to the users. The testing was carried out in two varieties i.e. Hippophae Rhamnoides and Hippophae Salcipholia of seabuckthorn at 2,500 m altitude. The capacity of the branch shaker and clipper were 5.0 and 6.2 kg/h with Rhamnoides and; 4.8 and 6.7 kg/h with Salcipholia, respectively which was 55-121% higher as compared to traditional. The damage to the fruits/berries was observed 108-171% higher in case of direct as compared to indirect method. The capacity was also observed higher in case of Salcipholia due to bigger size of fruit. Among all developed harvesters, the branch shaker having two half semi circular hooks (one fixed at upper end & another movable just below the top hook on one end of the pipe) and clipper with handle were found better. Moreover, the wire clip has also showed promising results but it is difficult to harvest in wild grown seabuckthorn orchards due to thorny nature of plant.

Introduction

The seabuckthorn (*Hippophae rhamnoides* L.) belongs to the family Elaeagnceae. The seabuckthorn is a medium deciduous shrub 2 to 4 m in height. The trees are dioecious meaning there are male and female plants. To ensure adequate pollination and suitable numbers of female trees, it is necessary for the orchard to have between 7 and 12% of the trees as pollinators. The plants have tremendous potential for functional food and nutraceutical uses. The berries have very high vitamin C and anti-oxidant properties. Only female plants produce fruit. Flowers are small, yellow and appear before the leaves being produced on three-year-old wood. Seabuckthorn plants are very hardy and can withstand temperatures of -45 to 103°F (-43 to 40°C). These plants are incredibly important natural resources in the Himalayan regions of India. It is also commonly found growing at high altitudes of 1,500 to 5,000 m. The plant will grow naturally in both sandy, and clay soils. In fact the plant will thrive in nearly any soil type, but it is extremely intolerant of shady planting sites. It is commonly planted to prevent soil erosion, but also serves as an economic resource for food and medicine products. Most of the operations from seeding to harvesting performed manually which are time consuming and labour oriented.

In Himalayas, about 12,000 ha area is under seabuckthorn mostly wild grown (Dwivedi *et al.* 2009) and it is distributed widely in the cold arid regions of Himachal Pradesh, Uttaranchal, Ladakh region of Jammu & Kashmir and in some parts of Sikkim. Three species of seabuckthorn are reported from India i.e. Hippophae Salcipholia, Hippophae Rhamnoides and Hippophae Tibetana. These species have different morphology i.e. size and shape of plants as well as fruits. There is no spacing from plant to plant and row to row as it has naturally grown plants. The small fruit, the density of the fruit on the branch, and occurrence of thorn on the plant are the disadvantageous during the harvesting. Thus it is difficult to move in between the plants and introduce particular device/ tools for all species. Hence, the harvesting is performed manually (**Fig. 1**) on periphery and collecting only 15-20% of the available fruits of the orchards which is cumbersome and also very time consuming. In addition, time for harvesting fruits is very short due to early snowfall. The fruit is orange when ripe at the end of August/beginning of September and is very difficult to harvest. Although the fruit is ripe, it is not easily removed from the tree. Estimates of 500 hours/hectare for fruit harvesting can be expected. Mechanical harvesters have been tried with little success. Other technique of removing the branch from the tree work well but it is still very labour intensive. Work is ongoing to find economical ways to harvest the fruit. Expected yields are around 5 to 7 kg per plant or 4 to 5 t/ha.

There is a need to investigate for harvesting fruits/berries system at full potential by making proper planning and strategies. This paper deals with studies carried out to design and develop the seabuckthorn harvester which suits to undulating topography and plants requirement with higher capacity and efficiency.

Theoretical Consideration

The appropriate timing of harvest and handling of fruit is of high importance in the management of a seabuckthorn orchard. Value of the crop is directly related to how the fruit is harvested and arranged for storage prior to processing. The small fruit size, short pedicel, forces required to pull off each fruit, the density of the fruit on the branch, and occurrence of thorn on the plant are the disadvantageous during the harvesting. Hence, the development work was carried out on the basis of earlier work done, tried and adopted globally in the harvesting of seabuckthorn fruit. Mostly two methods are involved in harvesting, which are described below:

Direct Method

In this method, the harvester is in direct contact with the seabuckthorn fruits while harvesting. It includes hand picking, fruit harvesting under frozen conditions, various types of manual harvester and robotic harvester. However this method of harvesting has to cause higher and severe damage to the plant with reduced yield. In Mangolia, a manual direct fruit comb harvesting method is developed which has a steel wire hook (clip or loop) for combing berries in two directions at once. This method has a capacity of 5-8 kg per hour (Avdai and Chimed-Ochir, 2003). Similarly, profiled teeth comb was designed and developed for harvesting craneberries and small fruits in Russia. The rate of harvesting was 48-80 kg in 8 hours (Tyarasov and Lesnoe, 1995). Robotic harvester has been developed to reduce the labour in harvesting but the cost of harvesting is high. Such harvesters are known to causes very less damage to fruits and plants (Grand d' Esnon *et al*., 1987)

A common method of hand harvesting involves cutting the branches off the tree and placing into a deep freezer until frozen. Frozen branches can then be banged on the inside of a drum or garbage can, knocking the frozen berries off. This process damages the berries, and they should process, or returned to the freezer for later processing. Mechanical harvesters have been of limited success. A mechanical harvester developed in East Germany is the only machine in the world designed specifically for use with seabuckthorn berries. This harvester removes the berries from the branches with brushes, but first the branches are cut from the trees. Using this method, only half of the orchard is harvested each year to allow for re-growth of the cut branches.

Fig. 1 Traditional system of harvesting fruit

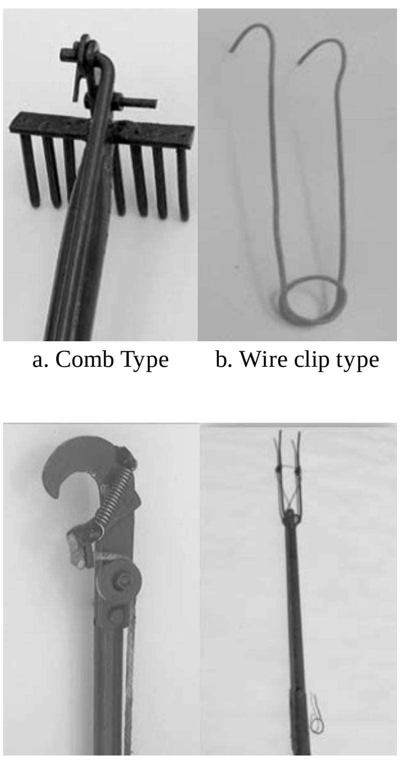
Indirect Method

In case of indirect harvesting, the harvester is not in the direct contact of the fruits which includes chemical harvesting, suction air type harvester, vibration based harvester, various type of static and mobile mechanical shaker (Mann, *et al*., 2001; Achrafi and Gatke, 1993). Generally indirect methods of harvesting have been found to be more effective, efficient and less destructive compared to direct methods of harvesting. In chemical method, the fruits were sprayed with Ethrel (ethephon) at 200-250 ppm until dripping for separating the berries from branches. A concentration of 250 ppm decreased the attachment force by 30% which also reduces the mechanized harvesting time by half (Trushechkin *et al*., 1973).

Design Consideration

On the basis of above studies, it was imperative to consider some design parameters as given below:

- It should be simple in design and easy to operate with minimum drudgery in wild grown seabuckthorn orchard.
- It should be light in weight to make the harvesting operation easier, simpler and more attractive to the users.
- The cost of harvester should be minimum and within the purchasing power of farmers.



a. Comb Type b. Wire clip type

c. Branch shaker type d. Clipper with handle type

Fig. 2 Developed tools/devices

- The berry damage should be as minimum as possible.
- The care and maintenance costs should be low.
- It should reduce the cost of operation.
- It should easily fabricated by local manufacturers.

The conceptual design of manual harvester was prepared for development of machine based on above methods and design consideration (Vatsa and Singh, 2010). An indigenous manual harvesters i.e. comb, branch shaker, wire clip and clipper with handle type were developed and fabricated for increasing capacity and efficiency.

Field testing

The developed tools were evaluated at Lahaul and Spiti in the field particularly in two plant varieties i.e. Hippophae Salcipholia and Hippophae Rhamnoides and compared with traditional method (beating with sticks on branches). The parameters such as time, outcome, damage, labour requirement were taken. Cost calculations were also carried out in accordance with the procedure given in IS code (BIS 1979).

Results and Discussion

Development of Fruit Harvester

The seabuckthorn fruit harvesters such as comb, wire clip, branch shaker & clipper with handle type were designed and developed (**Fig. 2**) in the Agricultural Engineering Workshop at CSK Himachal Pradesh Agricultural University, Palampur (HP) India. The detailed specifications (**Table 1**) of each harvester are described below:

Comb type

A pipe of size 1,000 mm of 25 mm diameter was attached with comb assembly having 8 spikes at spacing of 10 mm welded on angle iron at about 900. The comb has a provision for making the proper angle of comb on the branch with adjustable lever. Two types of the comb assembly i.e. straight and curved finger type were developed. The adjustable lever for comb will be helpful in making proper gripping on the branches while harvesting the berries by pulling action. The weight of the tool was more than 1.5 kg.

Wire clip type

A simple galvanized iron wire of 3 mm diameter was used to develop a wire clip for harvesting the seabuckthorn fruit. The wire has been folded in U-shape having size of 200 mm. Open end of wire was having clip shape for holding the branch. The harvesting is performed with clip by pulling the device in one direction on the branch.

Table 1 Specifications of developed seabuckthorn fruit harvester

Parameter	Mean Value			
	Comb type	Wire clip type	Branch Shaker type	Clipper with handle
Power required for operation	Manual	Manual	Manual	Manual
Overall dimensions (L × W × H), mm	1250 × 135 × 20	240 × 45 × 40	1250 × 80 × 20	1250 × 75 × 60
Weight of tools/ machine, g	1600	80	900	950
Size of harvesting unit, mm	135 × 100	45 × 40	150 × 80	75 × 60
Height Adjustment	Adjustable up to 1 m	No adjustment	Adjustable up to 1 m	Adjustable up to 1 m
Other Adjustment with lever	Direction of comb	Nil	Opening of hooks	Opening of Clip

__Branch shaker type__

Two semi-circular hooks (one fixed at upper end & other movable just below the top hook) were provided on one end of the 1,000 mm long pipe with 25 mm diameter. A gap of 20 mm maximum in between the hooks was maintained for fixing in stem of the plant. The tool weighs about 1.0 kg. A lever was provided to the adjustable hook for proper gripping of the branch. The seabuckthorn fruits will be harvested by shaking the branches with this tool.

__Clipper with handle type__

A mild steel rod of 5 mm diameter was used to develop a clipper by folding in U-shape for harvesting the fruit. Open end of rods have been provided in shape of clip for holding the branch and other end was attached with handle of 25 mm diameter pipe having a length of 1,000 mm. The weight of the tool was less than 1.0 kg. A lever was provided on the handle to operate the clip. The harvesting of fruits will be performed with clip by pulling the device in one direction on the branch.

Comb type

Wire type

Branch shaker

Clipper type

Fig. 3 Developed tool/harvester in operation

Table 2 Performance of manual harvesting tool/devices for Rhamnoides

Parameters	Developed Manual Harvester				Traditional system
	Comb	Wire clip	BranchShaker	Clipper with handle	
Capacity, Kg/h	4.5	5.4	5.0	6.2	2.8
Damage, %	35	38	14	30	32
Labour requirement, man-h/ kg	0.22	0.18	0.20	0.16	0.36
Cost of device, Rs	350	80	450	480	-
Cost of operation, Rs/kg	5.5	4.5	5.0	4.0	10.5

Table 3 Performance of manual harvesting tool/devices for Salcipholia

Parameters	Developed Manual Harvester				Traditional system
	Comb	Wire clip	Branch Shaker	Clipper with handle	
Capacity, Kg/h	5.1	5.8	4.8	6.7	3.1
Damage, %	30	25	12	28	30
Labour requirement, man-h/ kg	0.19	0.17	0.21	0.14	0.32
Cost of device, Rs	350	80	450	480	-
Cost of operation, Rs/kg	5.0	4.5	5.0	4.0	10.0

Performance Evaluation of Developed Tools/Devices

The performance of developed tools/devices was carried out (**Fig. 3**) on two varieties of seabuckthorn at altitude of 2,500 m above mean sea level in Lahaul Spiti Valley in Himachal Pradesh, India. The details of testing on both varieties are presented below:

__Rhamnoids__

The developed manual tools/devices such as comb, wire clip, branch shaker and clipper with handle type harvesters were evaluated for Rhamnoids variety (**Table 2**) in the wild grown seabuckthorn orchards and compared with traditional system of harvesting. It is clear from **Table 2** that the capacities of tools/devices were 4.5, 5.4, 5.0 and 6.2 kg/h with 35, 38, 14 and 30% damage by comb, wire clip, branch shaker and clipper with handle, respectively. The capacity was found 61 to 121% higher with developed harvesters as compared to manual method. The damage to the fruits was observed 114-171% higher in case of direct method as compared to indirect method i.e. branch shaker. Moreover, the fruit damage was also observed more or less same with manual beating with sticks and direct method of harvesting with developed tools and devices. The wire clip and clipper with handle showed promising results in both varieties of seabuckthorn but wire clip was not found promising in wild grown seabuckthorn orchards due to thorniness of plant and movements in between the orchards (Vatsa *et al*., 2009). In addition, the harvesting of fruit is also not possible with wire clip more than the height of a person.

Salcipholia

The developed tools/devices were also evaluated (**Table 3**) for Salcipholia variety. The capacities of tools/devices were observed i.e. 5.1, 5.8, 4.8 and 6.7 kg/h with comb, wire clip, branch shaker and clipper with handle, respectively. The capacity was found 55-116% higher with developed harvesters compared to manual method. The damage to the fruits was observed more or less same with manual beating with sticks and direct method of harvesting but 108 to 150% higher in case of direct method as compared to indirect method. The wire clip and clipper with handle showed promising results for this variety also but wire clip was not found suitable in wild grown seabuckthorn orchards as stated above for Rhamnoids. The fruit plucker faces injury with wire clip during harvesting due to thorn. The hook type branch shaker was also found better as compared to others but detaching the berries from branches was not possible in day time due to temperature rise. The study revealed that the frozen berries could easily be removed from the branches (Wolf & Wegart 1993).

Conclusion

Seabuckthorn is a rare plant and mostly wild/naturally grown in cold arid region of Himalayas. The fruit harvesting of seabuckthorn is very typical in nature and generally harvested manually by beating the plant branches with stick. Hence, four different types of manual harvesters i.e. comb, wire clip, branch shaker and clipper with handle were designed and developed to make the harvesting operation easier and more attractive to the users. The capacities of harvester were 4.5, 5.4, 5.0 and 6.2 kg/h in case of varieties Rhamnoids and 5.1, 5.8, 4.8 and 6.7 kg/h in case of varieties Salcipholia with comb, wire clip, branch shaker and clipper with handle, respectively. The branch shaker was also found better as compared to others but harvesting is not possible in day time due to high temperature. The capacity was found 55-121% higher for both evaluated varieties of seabuckthorn with developed harvesters compared to manual method. The damage to the fruits was observed 108-171% higher in case of direct method as compared to indirect method. Among all developed harvesters, the clipper with handle and branch shaker were found better.

REFERENCES

Anonymous. 1979. Guide for estimating cost of farm machinery operation. IS 9164:1979. Bureau of Indian Standards, New Delhi.

Achrafi, M. K. and R. Gatke. 1993. Technical parameters for mechanical shaking of single fruits of seabuckthorn. Gartenbauwissenscheft. 58 (5): 220-224.

Avdai, C. and G. Chimed-Ochir. 2003. Harvesting of seabuckthorn fruit in Mongolia. In: Seabuckthorn a Multipurpose Wonder Plant (V Singh *et al*.). Indus Publishing Company, New Delhi.

Dwivedi, S. K., T. Parimelazhagan, S. B. Singh and Z. Ahmed. 2009. Seabuckthorn (Hippophae spp: The Golden Bush). Satish Serial Publishing House, New Delhi.

Grand d' Esnon, A. *et al*. 1987. A self propelled robot to pick apples. ASAE Paper. pp 1037.

Mann D. D., D. S. Petkau, T. G. Crowe and W. R. Schroeder. 2001. Removal of seabuckthorn (Hippohpae Rhamnoides L.) berries by shaking. Canadian Bio-systems Engineering. 43(2):23-28.

Trushechkin, V. G., B. V. Lobanova, S. A. Ostreiko, I. P. Kalinina, V. D. Bartenev and V. M. Burdasov. 1973. The use of beta-chloroethylphosphonic acid for facilitating the detachment of seabuckthorn fruit in relation to mechanized harvesting. Sbornic Nauchnykh Rabot Nauchno Issledovatel 'Skii Zonal nyi institute Saduvodstva Nechernozemnot polisy. 6:168-173

Tyarasov, G. P. and K. Lesnoe. 1995. Implements for gathering wild berries. Sbornic Nauchnykh Rabot Nauchno Issledovatel 'Skii Zonal nyi institute Saduvodstva Nechernozemnot polisy. 6: 37-38

Vatsa, D. K., S. Singh and V. Singh. 2009. Status of Harvesting Tools for Seabuckthorn Fruit and its Adoption in North Western Himalayas of India. Paper Presented during the Fourth International Seabuckthorn Association Conference (ISA-2009) held at Belokuriha (Altai Region), Russia.

Vatsa, D. K. and S. Singh. 2010. Seabuckthorn Fruit Harvesting in Himalayas of India: Problems and Prospects. Paper presented during National Conference on Seabuckthorn held at CSKHPKV, Palampur.

Wolf, D. and F. Wegart. 1993. Experience gained in the harvesting and utilization of seabuckthorn. In Cultivation and Utilization of Wild Fruit Crops, 23-29. Braunschweig, Germany: ernhard Thalacker Verlag Gmbh & Co. (In German).

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Design and Development of Groundnut Planter for Power Weeder

by

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Abstract

Groundnut is the sixth most important oilseed crop in the world. The major groundnut producing countries in the world are India, China, Nigeria, Senegal, Sudan, Burma and the United States of America. It contains 48-50% oil and 26-28% protein, and is a rich source of dietary fiber, minerals, and vitamins. India stands second in the production of groundnut. Groundnut is grown on Million hectares worldwide with a total production of 35.367 Million metric tonnes in 2011-2012. India is a world leader in groundnut farming in terms of production area, with 5.95 million hectare and with a yield of 7.5 million tonnes in the year 2011 (Dept. of Agriculture, India). The country has exported 535,637.38 MT of the groundnut to the world for the worth of 4 billion USD during the year 2012-13. The planting operation is one of the most important cultural practices associated with crop production. Increases in crop yield, cropping reliability, cropping frequency and crop returns all depend on the uniform and timely establishment of optimum plant populations. A seed-cum-fertilizer should be developed for a power weeder to minimize the cost of operation.

The basic idea for mounting of groundnut planter to the power weeder is "the negative draft generation of the power weeder helps to reduce the positive draft requirement of groundnut planter". The row

to row spacing was also measured at different locations; it was observed that 30 cm spacing between two rows throughout the field. The depth and width of furrow opener was measured under field condition. It was observed that, the average width and depth of furrow opener was 10 cm and 5 cm respectively for entire row. Developed power weeder drawn groundnut planter consists of one ground wheels of diameter 38.12 cm, three plates provided mounted on the rotating shaft. The entire attachment was fixed on the frame. Ground wheel rotates the power transmit with the suitable gears and chain and rotate metering unit (3 plates) with attached spoons. Total length of the machine 1.2 m and width is 90 cm.

Key words: Groundnut planter, Power weeder, Positive draft, Negative draft.

Introduction

Groundnut is grown on large scale in almost all the tropical and sub-tropical countries of the world. Groundnut is the sixth most important oilseed crop in the world. The major groundnut producing countries in the world are India, China, Nigeria, Senegal, Sudan, Burma and the United States of America. It contains 48-50% oil and 26-28% protein, and is a rich source of dietary fiber, minerals, and vitamins. Groundnut is called as the 'King' of oilseeds. It is one of the most important food and cash crops of our country. While being a valuable source of all the nutrients, it is a low-priced commodity. Groundnut is grown on Million hectares worldwide with a total production of 35.367 Million metric tonnes in 2011-2012. Over 100 countries worldwide grow groundnut. The top 3 producers were China, India and USA, whose groundnut production was estimated to be 16.046 Million metric tones, 5.5 Million metric tonnes and 1.66 Million metric tonne respectively. (Madhusudhana .B). The groundnut plant is variable annual herb, which grows up to 50 cm. in height. The flowers of the plant develop a stalk which enters into the soil, forms a pod containing generally two seeds they become mature in about two months. The main groundnut varieties produced in India are KADIRI-2, Kadiri-3, BG-1, BG-2, Kuber, GAUG-1, GAUG-10, PG-1, T-28, T-64, Chandra, Chitra, Kaushal, Prakash, Amber. Groundnut plant belongs to the leguminous family and it is a tap rooted crop. The pods are located up to a depth of 7-10 cm usually referred to as pod zone. It takes from 120-150 man-hr to harvest a hectare.

Groundnut Importance

Groundnut is an important oilseed crop and oil content of the seed varies from 44-50%, depending on the varieties and agronomic conditions. It is also used in soap making, and in manufacturing cosmetics and lubricants, olefin, stearin and their salts. Kernels are also eaten raw, roasted or sweetened. They are rich in protein and vitamins A, B and members of the B2 group. The cake can be used for manufacturing artificial fibre. The haulms are fed (green, dried or silaged) to livestock. Groundnut shell is used as fuel for manufacturing coarse boards, cork substitutes etc. Groundnut is also of value as a rotation crop. The production is concentrated in the four states of Gujarat, Andhra Pradesh, Tamil Nadu and Karnataka.

Groundnut Sustainability

Groundnut is grown crop can be grown successfully in places receiving a minimum rainfall of 500 mm and a maximum rainfall of 1,250 mm. The rainfall should be distributed well during the flowering and pegging of the crop. The total amount of rainfall required for pre-sowing operations (preparatory) is 100 mm, for sowing it is 150 mm and for flowering and pod development an evenly distributed rainfall of 400-500 mm is required.

Groundnut is raised mostly as a rain fed Kharif crop, being sown from May to June, depending on the monsoon rains. Fertilizer recommended for rained crop is 6.25 tonnes farmyard manure and 10-25 kg nitrogen (N), 20-40 kg phosphorus (P_2O_5) and 20-40 kg potash (K_2O) per ha. The application of N should be made in two equal split doses, one before sowing and the other 30 days after sowing. In Andhra Pradesh, especially in Rayalaseema region groundnut is the major crop which mainly grown in Ananthapur, Chittor, Kurnool due to less annual rain fall. The soils of this region are predominately red sandy loams with characteristic subsoil hard pan. The Agro ecological conditions of Ananthapur district is Hot arid, Deep loamy and clayey mixed with red and black soils, Annual rainfall: 497 mm, Potential Evapotranspiration: 1,858 mm, Moisture availability period: 60-90 days, 1,858 mm

The technology constitute one of the major solutions to low productivity and the expansion of the production area associated with traditional hand tools used by the rural farmers (Mekki and Mohamed, 2011). The planting operation is one of the most important cultural practices associated with crop production. Increases in crop yield, cropping reliability, cropping frequency and crop returns all depend on the uniform and timely establishment of optimum plant populations. The selection, setting and operation of planting machinery directly influence seedbed conditions and may modify seed properties through, for example, mechanical damage.

The planting machinery is usually critically important in crop establishment. Planting machines modify the pre-existing seed and soil conditions, and dictate seed placement within the seedbed. The pre-existing conditions can be improved or impaired as a result. An essential requirement of effective machinery management is to identify the main components of these machine-soil-seed interactions. By understanding these relationships, those responsible for the planting operation can select, set and operate the machines to best meet the agronomic requirements for establishment (Tessier *et al*., 1991a).

Guruswamy *et al*. (2005) studied about Energetics of Groundnut Production in Red Soil under Bullock Farms in Raichur Region. The results indicated that a total input energy of 10,605.87 MJ/ha was required by the indigenous implement package commonly used by the farmers whereas the improved implement package required a total input energy of 9,178.90 MJ/ha for groundnut production. Jayanthi *et al.* (2012) studied about performance evaluation of power drawn six row groundnut planter. Sawsan Kamal Eldin Hassan *et al*. (2012) studied about "Performance of Animal Drawn Planter on Establishment and Productivity of Groundnut in North Kordofan of Sudan". The treatments were arranged in randomize plots with three replicates and analyzed by t-test. The results showed that there were highly significant differences between the animal drawn planter and manual for a parameters such as time for sowing, sowing depth, plant population, uniformity of seeding, in groundnut cultivation weeding efficiency, seed and hay yield (kg/ha). Dahab M. Hassan *et al*. (2013), studied about Development of Animal Drawn Groundnut Planting Machine for Small Holdings Farmers in North Kordofan of Sudan.

The major reasons for the demand for groundnut machinery are to reduce drudgery, to improve timeliness, and to increase productivity and income. The most desirable machines indicated by farmers are stripper, digger, and planter for irrigated area; planter, stripper, and weeder for rainfed area; and stripper, weeder, and seed shelter for area using residual soil moisture Chinsuwan *et al*., 1991).

- The number of passes in the field can be reduced (cost of cultivation reduces)
- With the help of tillering unit of power weeder, the tillering operation can be carried out.
- Power weeder could be used as a multipurpose tool by minor modifications.
- The negative draft generation of power weeder helps to reduce the positive draft requirement of groundnut planter

According to the nature of the deep loamy and clayey mixed red and black soils which is described as light and therefore is exposed to both wind and water erosion. Power weeder drawn planter has impact on reduction of time for agricultural operation. The short growing season and the scarcity of labour make high need for the intermediate technology to be used for deep loamy and clayey mixed red and black soils in Anathapur district.

In the context of the above knowledge, there is a strong need for development and evaluation of power weeder drawn groundnut planter for small scale farmers with suitable seed to seed spacing and row to row spacing. The basic idea for mounting of groundnut planter to the power weeder is "the negative draft generation of the power weeder helps to reduce the positive draft requirement of groundnut planter".

Materials and Methods

The self propelled groundnut planter was designed as a functional and experimental unit. The design of machine components were based on the principles of operations, tested and compared with the conventional method, to give a correct shape in form of prototype also as to give adequate functional rigidity for the design of machine.

Planter

Planter is sowing equipment used for sowing of bigger seeds. Row to row and plant to plant spacing is maintained in a planter.

Functional requirements of planter

The planter was designed to fulfil the following functional requirements:

i) To meter the seed/groundnut properly.
ii) To place the seed/groundnut and fertilizer in the soil to a specified position.
iii) To groundnut the seed i.e. groundnut.

The mechanical functional requirements of different individual units of machines are given below:

Seed Hopper

i) It should hold sufficient quantity of groundnut seed.
ii) The shape of the hopper should be such as it allows free picking of groundnut seed into the seed metering device without bridging.
iii) It should be easily accessible and visible to the operator.
iv) The shape of the hopper should be along the length of the frame by which the load could be distributed uniformly.

Fertilizer Hopper

i) It should hold sufficient quantity of fertilizer.
ii) There must be an arrangement for controlling the rate of application of fertilizer.
iii) There should be provision in the hopper for de-clogging the fertilizer.
iv) It should be easily cleanable.

Seed Metering Device

i) It should be able to pick the groundnut seed from hopper and drop into the dropping unit (funnel) uniformity.
ii) There should not be any internal or external damage to the ground-

nut seed.
iii) There should be continuous flow of groundnut seed.
iv) It should maintain the proper seed to seed distance.

Seed Dropping Device
i) It should place the groundnut seed on the furrow bed at a specified distance.
ii) It should not cause any injury to the groundnut seed.
iii) Height of fall of the groundnut seed should be minimum.

Fertilizer Metering Device
i) It should meter the fertilizer at the specified rate.
ii) There should be continuous flow in the fertilizer tube.
iii) There should not be any choking in the tube.
iv) The fertilizer should be drop below the seed.

Furrow Opener for Fertilizer
i) It should maintain the required depth of fertilizer.
ii) Width of furrow should be sufficient to facilitate lateral placement of fertilizer.
iii) There should not be any choking in furrow opener.

Now a day's power weeder demand has been increasing day by day due to less due to its working efficiency and economic. The power weeder consists of a tillering unit which gets the power from the petrol engine with belt and pulley arrangement. The tillering unit consists of four discs which are having four number of blades mounted on it. During the operation the blades penetrate in to the soil and break the hard pan, also pulverises the soil. Due to its forward motion, the tillering unit creates negative draft which helps to pull any other machine. By using this negative draft, the power

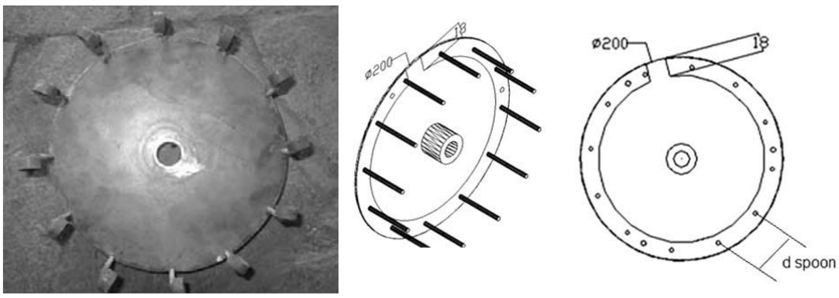

Fig. 1 Vertical plate cup or spoon type picking metering device

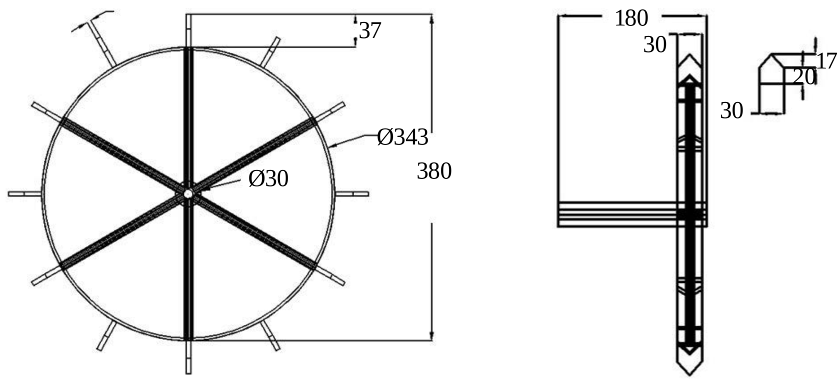

Fig. 2 Front and side view of ground wheel for groundnut planter

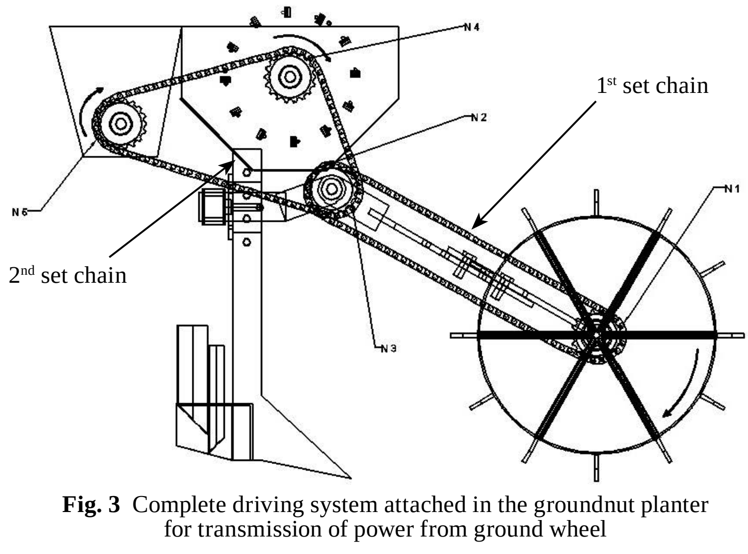

Fig. 3 Complete driving system attached in the groundnut planter for transmission of power from ground wheel

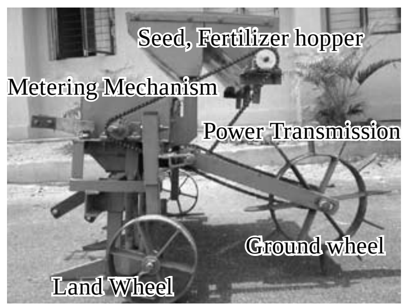

Fig. 4 The complete view odf designed and developed ground nut planter

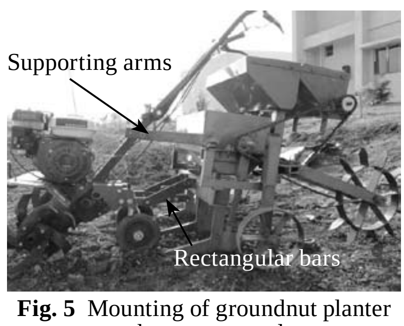

Fig. 5 Mounting of groundnut planter to the power weeder

weeder may be converted as dual purpose machine. Based on the power weeder dimensions, a matching ground nut planter was designed and developed. The planter was designed for three rows. It consists of Vertical plate cup or spoon type picking metering device (**Fig. 1**) for each row. An adjustable nut and bolt arrangement was made for easy adjustment of row to row spacing. The plant to plant spacing also may be changed by varying the gear ratio of the ground wheel and the metering shaft. A ground wheel was designed for power transmission to the seed and fertilizer metering devices. As per recommendation (Veeramani and Subramanyam, 2011) for plant to plant spacing is 10 cm. Peg type wheel was selected for use due to less slip and suitability of soil. The diameter of the wheel was 38.2 cm, width of 3 cm and thickness of 0.5 cm. Twelve spikes (5 cm × 3.0 cm × 0.5 cm) were provided on the outer periphery of the wheel to develop sufficient grip to the rotating wheel. The spokes were made up of mild steel round bars or flat bars pointed at the end. The motion of a given point on the wheel follows a cycloid path. The spokes enter the ground vertically and leave the surface upwards. Hence, soil coming in contact with the peg was pushed downward but not taken upwards. Power developed due to the rotation of the wheel was transmitted to the seed and fertilizer shafts with the help of two sets of chain and sprocket arrangement. **Fig. 2** shows the front and side view of ground wheel for groundnut planter. A depth control-cum transport wheel (Land wheel) was designed and fabricated and is shown in **Fig. 4**.

Chain and sprocket arrangement was used for power transmission from the ground wheel to seed and fertilizer metering devices. The gear ratio of ground wheel, seed metering unit and fertilizer metering unit was one. The gear ratio was calculated as follows:

$$\frac{N_1}{N_2} = \frac{N_2}{N_3} = \frac{N_3}{N_4} = \frac{N_4}{N_5}$$

N_1 = Number of teeth in gear of ground wheel = 18;
N_2 = Number of teeth in first follower gear = 18;
N_3 = Number of teeth in second follower gear = 18;
N_4 = no of teeth in gear of seed metering device = 18; and
N_5 = Number of teeth in gear of fertilizer metering device = 18.

$$\frac{18}{18} = \frac{18}{18} = \frac{18}{18} = \frac{18}{18}$$

Thus the gear ratio was 1:1 for the whole metering assembly. The number of revolution per minute of the ground wheel was same as that of number of revolution per minute in the seed and fertilizer metering unit. The complete driving system attached in the groundnut planter for transmission of power from ground wheel is shown in **Fig. 3**.

Therefore, in one revolution the ground wheel covers 120 cm, so the seed dropped in one revolution of ground wheel was found to be in 12 numbers. For vertical plate metering device the MS plate having 3 mm thickness was used. The number of revolution per minute of the ground wheel was same as that of number of revolution per minute in the seed and fertilizer metering unit. Therefore, number of spoon of metering device was 12. The the periferal distance between two spoons was calculated as 5 cm. The complete view odf designed and developed ground nut planter is shown in **Fig. 4**.

Development of a Power Weeder Drawn Groundnut Planter

The basic idea for mounting of groundnut planter to the power weeder is "the negative draft generation of the power weeder may use to reduce the positive draft requirement of groundnut planter". The planter was mounted to the power weeder with the help of two supporting arms at the middle of the machine which are for supporting the load as well as distribution of load and two rectangular bars at the bottom on either side of the machine for stability as well as for pulling the planter under transport and field conditions as shown in **Fig. 5**.

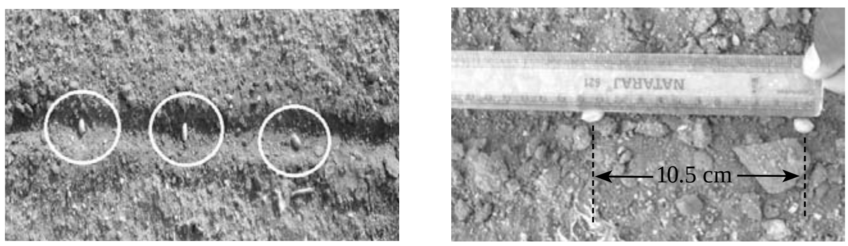

Fig. 6 Measurement of plant to plant distance under field condition

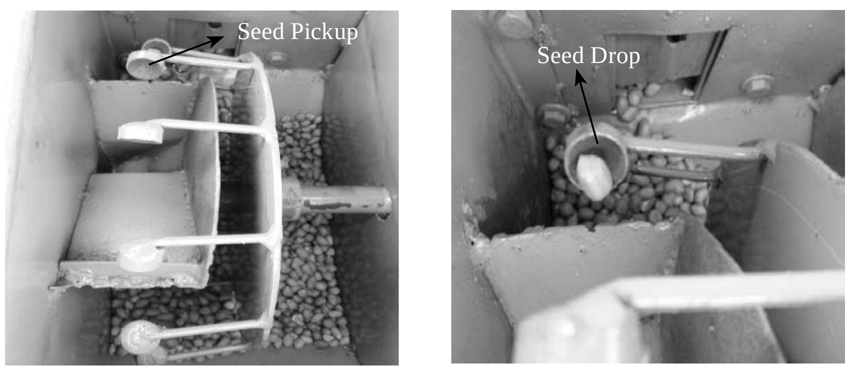

Fig. 7 Close view of precision seed metering mechanism

Results and Discussions

Field Demonstration of Power Weeder Drawn Ground Nut Planter

The designed and developed groundnut planter for power weeder was tested at research farm of College of Agricultural Engineering, Madakasira. A 10 m × 10 m plot was selected for evaluation of the power weeder drawn ground nut planter. The ground nut seeds were placed inside the hopper about half of its capacity and the machine were operated at the forward speed of 1.5 km/h on unploughed land. The plant to plant spacing was measured at different locations in the selected plot as shown in **Fig. 6**. It was observed that, the spacing between two plants is 10 cm at different locations, but in some places, the spacing is ranges from 10 cm to 12 cm, it may be due to seed movement in the furrow. Also observed that, the metering mechanism was dropping only one seed most of the times as shown in **Fig. 7**; in some places it was observed two seeds, the reason was because of small size of seeds (length is greater than the width) more seeds are occupying the seed metering cup.

The row to row spacing was also measured at different locations; it was observed that 30 cm spacing between two rows throughout the field. A provision was made for increasing or decreasing the row to row spacing by adjusting the U-clamp holder of tines. It was also observed that the seeds are dropping exactly at the centre of the furrow throughout the field also all the rows are in straight. The average width and depth of furrow opener was 10 cm and 5 cm respectively for entire row. The provision was made for changing of depth of operation by adjusting the height of furrow opener also the height of land wheel. The horizontal component of resultant force required to pull a machine in the field is draft. The draft requirement of the machine was calculated by the multiplication of soil resistance and its cross sectional area ($F_x = a \times W_w \times P_k$). The total draft requirement was found to be 220.8 N.

The cost of operation of the machine per hour as well as per ha was presented in **Table 1**. The machine cost was taken including the prime-mover cost, which may be used in other farm operation also. The annual use of the machine was taken only 200 h/year, which may be increased by changing only metering unit of the machine and can be used for other crops like maize, groundnut, soybean etc.

Table 1 Calculation of cost of calculation per hour and per ha of ground nut planter

S. No.	Particulars	Amount
1	Cost of machine , USD	202
2	Life of the machine (y)	10.00
3	Annual use (h)	200.00
4	Fixed cost, USD	20.20
5	Depreciation, USD.	0.09
6	Interest, USD	0.06
7	Repair and maintenance, USD	4.04
8	Housing, USD	00.00
Sum of (1 to 8)	Fixed cost (USD/Year)	226.39
A	Fixed cost (USD/h)	1.41
B	Operational	
1	Wage of 2 operator (USD/day*),	4.66
2	Cost of fuel (1 lit/h), USD	1.21
3	Cost of oil and lubricants (0.5% of oil cost), USD	0.03
Total of B	Operational cost (USD/h)	0.93
Total of (A+B)	Machinery cost, (USD/h)	2.33
a.	Cost of operation, USD /ha	36.08
b.	Saving over manual methods, USD/ha	44.72
c.	Saving over manual dibbling percentage	55.35 %

* 1 day i.e. 8 hour of work

From calculation it was found that cost of operation of the machine mainly depends upon its annual use. In present assumption the fixed cost was found to be 1.4 USD whereas, operational cost as 0.93 USD. Including both fixed and operational cost the machinery cost per hour was calculated as 2.35 USD/h.

The following conclusions were drawn from the above study.

- The power weeder drawn ground nut planter was designed and developed.
- The planter was tested under field conditions.
- The designed seed metering mechanism was able to deliver the precise amount of seeds (only one seed).
- The power weeder could be used for multipurpose and it helps to reduce the draft requirement of the implement ("the negative draft generation of the power weeder helps to reduce the positive draft requirement of groundnut planter".)
- For sowing one ha of land the planter required 36.08 USD/ha which was much more less as compared to manual dibbling method which required 65 man days and required additional of 44.72 USD. So, the newly developed machine saves 55.35% of money over traditional methods.

REFERENCES

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Assessment of Design Variations in Tractor-Trailer Systems on Indian Farm for Safe Haulage

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Abstract

In India tractor trailer system is one of the most popular means of rural haulage particularly under off-the-road conditions. Variations in dimensions and other design parameter and operating conditions of the trailers in Haryana and Maharashtra states of India were assessed in order to ascertain different factors involved in instability. Haryana had almost equal share of single and double axle trailers, in Maharashtra the use of single axle trailer was 36% more in comparison to double axle trailer. Haryana state witnessed more variation in physical dimensions for both single and double axel trailers due to wide variations in commodity to be transported as compared to Maharashtra state. Inter-state variation in instability response of the operators was higher on sloppy conditions compared to normal road conditions and also the material loaded ranged from 0.5 tonne to 12 tonne in the single axel trailer whereas 0.8 to 15 tonne in double axel trailer. The stake height in case of heavy material ranged between 0.5 to 2.7 m; the lowest for brick and the highest for sugarcane. Single axel trailer were less equipped with safety provisions like braking system, safety emblem and rear light indicators than that of double axel trailer.

Introduction

Tractor is used in multifarious ways in rural India to accomplish different agricultural operations including haulage of agricultural produce and other materials. Tractor availability per 1,000 ha is one of the indicators of mechanization level for a given region. Tractor population in India has increased multi-fold during the past half century. Starting from production of 880 units in 1961, tractor production per year has crossed 6.0 lakhs per year mark. The tractor sale in India increased from 247 thousands (2004-2005) to 614 thousands (2012-13), (Annual report 2012-13, Ministry of Agriculture, GOI). The total number of tractors on Indian farm is estimated as more than 4.5 million. The common equipment with tractor owners includes cultivator, harrow and trailer of different capacity and design. Thus, there is large population of tractor trailers in the country. In fact, tractor trailer system is one of the most popular means of rural haulage particularly under off-the-road conditions in India. Although, it has become lifeline of rural transport, the poor design of trailers and its improper operation leads to accidents resulting often into loss of lives and materials. Globally, India ranks third in total number of road accident injuries after USA and Japan, with 523 thousand persons injured per year. Tractor accidents account for 2% of total fatal injuries on rural highways. A total of 33% of accidents are caused by cars and three-wheelers, 29% by motorized two wheelers, 29% by trucks and 7% by buses (Anonymous, 2010) on Indian roads. Keeping the importance of safety of man and material in rural India, safe haulage of goods and agricultural produce by tractor trailers needs greater attention.

The safe haulage by tractor trailers depends on sound trailer design and proper operating conditions. A sound design of tractor trailer must ensure safety and stability of the system (Sagi *et al*., 1973). Improper design and uneven farm roads, unsystematic loading pattern of different types of material are the major accident causing factors. Lack of knowledge with respect to design parameters of tractor trailers and subsequently improper manufacturing has led to instability in both laterally and longitudinally. Many a times, improper design leads to excessive material consumption resulting into increased cost. Lack of skill and knowledge with respect to tractor trailer operations is also a major reason for tractor trailer accidents. In fact, the operating conditions often affect the stability of the tractor-trailer during transportation of materials. Many a time, the operating conditions, both off-the-road as well as on-the-road, are not favorable to maintain the equilibrium of tractor-trailer system which may often lead to accidents. Such accidents often victimize persons other than the operators like farm workers and passerby. Therefore, to avoid injury and loss of human life and property, safe operation of tractor trailers needs to be ensured by selecting proper design parameters and sound manufacturing process. There is serious lack of design data on tractor trailer. Keeping this in view, design variations in trailer design in selected states of India was assessed in order to ascertain different factors involved in instability of tractor trailer so that proper remedy can be developed.

Materials and Methods

The tractor with trailer is of paramount importance in haulage of agricultural produce and different other materials in rural areas. The variations in the design parameters of trailers have been observed to suit different terrain conditions and nature of materials to be transported. In the present study, the information was collected from the operators of tractor trailer on different relevant aspects including details related to dimensions and other design parameter and operating conditions of the trailers.

Selection of Study Area

For a country like India, where large variation is observed in agro-climate, soil, cropping and terrain conditions, different design of agro machinery is also required. Such variations warrant changes in design and operating conditions of tractor trailer also. The design variations are also desired to accommodate different material to be handled. State wise variations are also observed depending upon the cropping pattern and terrain conditions. For the present study, two states i.e. Haryana and Maharashtra were selected based on variability in the design of the trailers operating conditions. The main use of tractor trailer system in Haryana was for transportation of crop produce; however, a large variation in loading patterns of the materials was observed. The study area of Haryana was a typical representation of agriculturally advance regions where tractor trailers were used more for transportation of agricultural produce and input and less for non-agricultural works. In case of Maharashtra region, tractor trailers were in use more for transportation of non-agricultural commodities. However, Maharashtra is another agriculturally progressive state particularly in sugarcane producing regions.

Sampling Design and Data Collection Method

The specific objectives of this study was to collect information on use pattern, operating conditions and design variations of tractor trailer system in selected villages of the study areas. The information was analyzed to identify different factors causing instability in tractor trailer system. A two stage stratified random sampling technique was adopted for selecting the states, districts and villages and respondent of tractor trailer users. The study was carried out in three districts of Haryana namely Karnal, Jhajhar and Panipat and another three districts of Maharashtra namely Ahmednagar, Kolhapur and Sangali. From the three selected districts of the respective two states, three villages from among the ones having larger tractor trailer population were randomly selected. The respondents were further selected randomly from the selected villages.

All the required primary data were collected from trailer operators engaged in farming using a schedule by personal interview (Lande, 2014). The schedule for data collection had queries related to types of trailer with different design variations with respect to size of box (length, width, and height), hitching length and axel position. The information was also collected on different types of agricultural and non-agricultural produce handled. The schedule also included queries related to variations in loading pattern which is many a times the root cause of instability and potential threat for accident. The schedule was designed to help collect the information on operating conditions and operators responses related to comfort and safety while operating under various road conditions and percentage time distribution for handling different loading materials to ascertain relative use of the trailer for handling different materials. The primary data was screened and collated to prepare a master table. All the tractor trailers of particular study area were grouped as single axle and double axle trailer. The responses of the

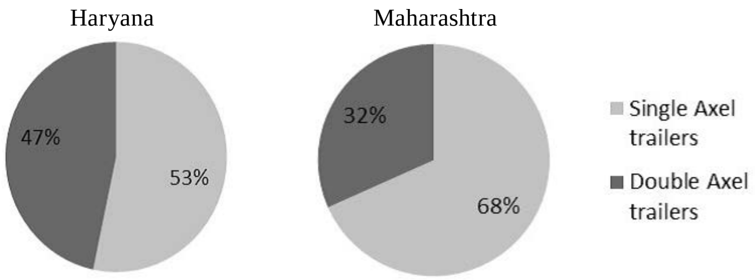

Fig. 1 Distribution of single and double axle trailers in study areas

tractor trailer operators were also collected while operating trailer under different conditions i.e. normal plain road condition, upward and downward road condition including reversing condition. The information related to percentage time taken to use the trailer for loading material throughout the year was also collected.

Design Variables of the Tractor Trailers

The data on design variation were collected by actual measurement of trailer dimensions. The loading of different materials, weight, and height of the material on the trolley and the pattern of arrangement were observed.

The factors which affect the tractor trailer stability are type of trailer, size of trailer and capacity of trailer. The data on these aspects were taken and their potential effect on tractor trailer stability was analyzed. The material holding boxbox is most important part a trailer. The box size is considered to be most critical parameters for trailer stability during transportation of different types of materials. The size of box i.e. amount of loaded material and the loading pattern directly affect the location of centre of gravity of trailer system. The box size in terms of length, width and height; hitching length, location of the axel were measured during the survey study. In single axel trailers, hitching length and axel location directly affects the weight transfer during the operation particularly under uneven terrain conditions. The location of the axel was identified as its distance from the rear end in case of single axel trailer whereas in double axle, it was distance between two axels. Data related to availability of safety provisions on the trailers system like braking system, rear side safety vehicle emblem and rear light indicators were also collected.

Analysis of Data

The data collected during the survey was analyzed with the help of computer based EXCEL software package. To begin with data was checked thoroughly for corrected. For each study area, one master table was prepared on excel. Both dependent and independent variables were identified. Such data were used to generate relationship among dependent and independent variables.

Results and Discussion

The design variation of the single and double axel tractor trailers of two states and six districts were analyzed (**Fig. 1**). The dimensions of the tractor trailer varied with the regions. The pattern of material loading, terrain condition and the type of trailer available were different. The two operating conditions on which the trailer stability mostly relies were ground conditions and material loaded in tractor-trailer system. But the stability of tractor trailer depended on design parameters of trailer system and geometric dimensions of the trailer system.

State Wise Variations in Tractor Trailer Use Pattern

A variation in use pattern of single and double axle trailer was observed in two selected states namely Haryana and Maharashtra. Whereas, Haryana had almost equal share of single and double axle trailers, in Maharashtra the use of single axle trailer was 36% more in comparison to double axle trailer. The choice of single and double axle trailer depended on type of material, loading pattern and farmers financial capability and the mindsets. These situations were favorable to famers of Haryana leading to use of 47% of double axle trailer in comparison to 32% in Maharashtra.

Design Variations in Tractor Trailer System

Design variations particularly in terms of physical dimensions were noticed in the study areas. In case of single axel trailer the variation of 53.8%, 50% and 192.3% in length, width and height respectively were observed. Where as in case of double axle trailers, the corresponding variations were 22.8%, 31.2% and 120%, respectively (**Table 1**).

A state wise variation in physical dimensions of single axel trailer was also observed; in Haryana the variation in length, width and height

Table 1 Design variation in the tractor trailer

Physical dimension		Single axle trailer		Double axel trailer	
		Haryana	Maharashtra	Haryana	Maharashtra
Size of the box	Length, cm	304.8-426.7	277.4-381.0	365.8-426.7	350.5-430.4
	Width, cm	182.9-228.6	152.4-201.2	182.9-220.0	167.6-213.4
	Height, cm	60.9-98.0	33.5-88.4	45.7-76.2	68.6-100.6
Hitching length, cm		91.4-150.0	76.2-149.9	100.0-166.4	96.0-233.4
Axle position, cm		130.0-153.0	30.5-128.0	230.0-325.1	127.3-278.1

were 40%, 25% and 60.8%, respectively. In Maharashtra the corresponding variations were 37.4%, 32% and 163.6 per cent. In case of double axel trailer, the variations in length, width and height were 16.7%, 20.3% and 67.67% respectively in Haryana and 22.8%, 27.3% and 46.7% respectively in Maharashtra. The variation in physical dimensions in case of single axel trailers were more pronounced than that in case of double axle trailer. In general, Haryana witnessed more variation in physical dimensions for both single and double axel trailers due to wide variations in commodity to be transported. Maharashtra did not experience large variations in dimensions due to less variation in the commodity.

This was not a welcome state and indicated that proper design standards were not followed in tractor trailer manufacturing. To ameliorate the situation, it is necessary to develop proper design dimensions for tractor trailer systems to be operated by different capacity tractors as exist in case of threshers. This may also need suitable changes in ground clearance and hitching system. Variations were also observed in material holding capacity as observed in case of tractor trailers in the study areas. In case of single axle trailer the capacity ranged between 1.88 to 9.56 cubic meter where as in double axle trailer it was 3.05 to 7.25 cubic meter. In Haryana, the cubic capacity of single axel trailer ranged between 3.39 to 9.56 cubic meters; where as it was 3.05 to 7.15 cubic meters for double axel trailer. However in Maharashtra, the cubic capacity of single axle trailer varied from 1.88 to 4.31 cubic meters and it was 4.11 to 7.25 cubic meter for double axle trailer. The variations in holding capacity may be necessary as the density of the different materials to transport also varies. In fact, trailer capacity should be given in terms of load carrying capacity not volume with sufficient space to accommodate different type of agricultural produce. The designed tractor trailer capacity must be in accordance with the power rating of the prime mover.

Variations were also observed in case of hitching length. In case of single axel trailer, variation in hitching length ranged between 64% and 96.67% in Haryana and Maharashtra respectively. However, for double axled trailer it was ranged between 66.4% for Haryana and 143% in Maharashtra. The average hitching length in Maharashtra and Haryana were 121.68 cm and 127.78 cm respectively.

The position of axle in both types of trailers affects stability; therefore, the dimensions related to its position in trailers were measured. In single axle trailer, axel position is the distance from back of trailer to axle while in double axel trailer it is the distance between two axles. In single axel trailers, the axle position variation was ranged from 17.69% in Haryana and it was 320% in Maharashtra. The average axle position in Haryana and Maharashtra for single axle trailer were 146.73 cm and 94.08 cm. Thus, the axel locations of single axel trailers were closed to rear end in Maharashtra as compared to Haryana. This resulted into more hitch load in single axel trailer of Maharashtra than that of Haryana which will be a possible reason for accident.

Operating Road Conditions Verses Tractor Trailer Stability

The information on tractor trailer stability for both single and double axle trailers on varying road operating conditions was collected. In fact, the tractor operators were asked about their subjective assessment of tractor trailer system instability. The assessment was based on ease of drive and imbalance in operator's position. The subjective responses of the operators were analyzed to determine the extent of instability under different operating and system design conditions. In general, under different road conditions double axle trailers was more stable than the single axel trailer which was as per the expectations. In single axle trailer, the more instability might have been caused by overloading and higher speed and on top of it bumpy rural roads. Although the extent of instability varied up to 90.2% in case of single axle trailer and 78.9% in case of double axle trailer (**Table 2**), taking into consideration the overall scenario the double axle trailer may be preferred. For example, on the normal road conditions, 60.7% operators of single axel trailers observed instability of varying extent; whereas 38.9% operators observed instability in case of double axel trailer. Thus, 21.8% operators observed that double axel trailer was more stable than single axel trailer. An appreciable variation in instability response by the

Table 2 Operators % response against instability under varying road conditions

Operating condition	Single axle trailer			Double axel trailer		
	Haryana	Maharashtra	Average	Haryana	Maharashtra	Average
Normal (Plain) road	53.1	68.3	60.7	35.7	42.1	38.9
Road with upward slope	62.5	80.5	71.49	60.7	78.9	69.8
Road with downward slope	75	90.2	82.62	71.4	78.9	75.2
Reversing the tractor with trailer	65.6	73.2	69.39	67.9	68.4	68.1
Overall average	64.1	78.1	71.1	58.9	67.1	63

operators was observed between the states also. On normal road condition, the operators from Maharashtra complaint more about instability problem for both single and double axle trailers; in case of single axle 15% more operators from Maharashtra felt instability in comparison to those of Haryana. The factors responsible for this variation may include road and load conditions in addition to operator's psychology. The operators of Haryana seemed to be more risk taking. The road slope, both upward and downward, caused more pronounced effect on tractor trailer system. Under sloppy conditions, more than 70% operators of both types of trailer observed instability of varying levels. Inter-state variation in instability response of the operators was higher on sloppy conditions vis-a-vis normal road conditions. On upward slope, for both single and double axel trailers, a variation of about 18% was observed in operators' response about instability. Interestingly, under this operating condition response with respect to single and double axle trailers was the same indicating that under sloppy conditions, the self-mental balance and psychology of the operator had more impact on instability assessment in comparison to the design variations. On down ward slope conditions, the instability became further pronounced and the variations with respect to inter-state or between single or double axle trailers were more. Imbalance of forces under down slope conditions, particularly when the tractor trailer system is not tightly jointed, led to yawning action of the system. On the road with upward slope, the difference in instability responses by the operators was very marginal (**Table 2**); whereas the same was large to the tune of ~7.0% in case of downward. The instability response by the operators when reversing the system was almost same both for single and double axel trailers. Interestingly, under this condition, even the interstate variation was not large; in case of double axle trailers there was less than 1.0% variation between the two states and in case of double axle it was to the tune of 7.0%.

Loading Pattern of Tractor Trailer System

Information on loading pattern of tractor trailer system including load and stake height was collected through direct measurement. The load and stake height varied with the material selected and design of the trailer. The inter-state variations in this regards were also noticed. The material loaded ranged from 0.5 tonne to 12 tonne in the single axel trailer whereas 0.8 to 15 tonne in double axel trailer. A mixed pattern was observed with respect to loading tonnage, for both high density and low density material, in case of single axel trailer when inter-state comparison was made. For example, in high density category; the sugarcane average loading ranged between 9.5 to 11.5 tonne between to selected states (**Table 3**). In case grain, as there is possibility of wide variation, the loading tonnage for a single axle trailer ranged between 6 to 15 in case of Haryana and 5 to 10 in case of Maharashtra. This clearly indicated that a wide variation in case of grain was observed unlike in case of sugarcane. These variations in loading tonnage were directly linked to the stake height; lighter the material more the stake height. This may lead to imbalance loading pattern resulting into unsafe operation or accident. In case of lighter material like straw the loading tonnage in single axel trailer ranged between 0.5 to 2.5 tonne and 0.5 to 1 tonne in Haryana and Maharashtra, respectively. The corresponding stake height was observed as 1.75 to 3 m in Haryana and 1.5 to 2 m in Maharashtra. The stake height is bound to be more in case of lighter material leading to large shift in centre of gravity of the system which, in turn, may lead to the accident. It is advised that, a proper recommendation with respect to lighter and heavier material loading pattern in tractor trailer must be worked out keeping in view the design variations, material handled and road and terrain conditions.

In case of double axel trailer, both tonnage capacity and stake height were large. For example in case of sugarcane average loading ranged between 9 to 15 tonne in case of Haryana and 10 to 20 tonne Maharashtra, respectively. Whereas, in case of grain, the loading tonnage ranged between to 6 to 15 tonne in Haryana and 5 to 17 tonne in Maharashtra (**Table 3**). The stake height

Table 3 Capacity and height of stack of material of the tractor trailer system

Material	Single axel trailer				Double axel trailer			
	Haryana		Maharashtra		Haryana		Maharashtra	
	Capacity (Tonnes)	Stack Height (m)	Capacity (Tonnes)	Height of stack (m)	Capacity (Tonnes)	Height of stack (m)	Capacity (Tonnes)	Stack Height (m)
Sugarcane	9.0-10.0	1.5-2.4	10.0-12.0	1.5-3.0	9.0-15.0	1.5-2.7	10.0-20.0	2.0-3.1
Grains	6.0-15.0	1.0-1.5	5.0-10.0	1.5-2.0	5.0-17.0	1.0-1.5	7.5-15.0	1.5-2.7
Straws (Bhusa)	0.5-2.5	1.75-3.0	0.5-1.0	1.5-2.0	0.8-2.5	2.0-3.0	1.0-2.0	2.0-2.5
Bricks	1.5-5.0	0.45-1.0	3.0-6.0	0.5-1.0	1.2-12.0	0.5-1.5	5.0-10.0	0.9-1.5
Sand	6.0-12.0	0.5-2.5	5.0-7.0	0.5-1.0	5.0-10.0	0.6-1.2	6.0-7.0	0.45-1.0

in case of heavy material ranged between 0.5 to 2.7 m; the lowest for brick and the highest for sugarcane. This is an alarming situation and invites immediately attention for a recommendation of appropriate stake height and loading tonnage for different category material. They should help avoiding under utilization as well as safe guard against overloading and possible accidents.

Provision of Braking System, Rear Side Reflector

In the study area, it was observed that the braking system was provided only in the double axel trailer and it was not available in the single axel trailers. Also only 3.52% of trailers were equipped with braking system (**Table 4**). As the braking system provision in tractor trailer system controls the change in moment of inertia of the material loaded on the trailer box along with weight transfer from the trailer to the tractor, it greatly affects the stability and safety of the tractor trailer systems. Hence, in both study areas the trailers operated with higher loads were operated with huge risk of accident.

In single axel and double axel trailer, the safety emblem was fitted on 55.15% and 93.8% respectively. The rear light indicators were provided in 39.14% in single axel trailer and 81.39% in double axel trailers. Also many a times, safety emblems and rear light indicators are not visible due to material overloading, this may invites tractor-trailer accidents.

In Haryana, 1.78% trailers had been fitted with braking system whereas 5.26% trailers had the braking system in Maharashtra. The safety vehicle emblems were fitted with 69.87% in Haryana and 79.08% in Maharashtra. Single axel trailer were less equipped with safety provisions than that of double axel trailer. Thus absence of braking system and safety emblem may cause safety threats to operators and trailer.

Conclusions

Overloading, improper stake height and high speed are major operating factors that lead to accidents. For stability of tractor-trailer system, it is necessary to ascertain different factors, which disturb equilibrium during transportation. The safe haulage of tractor trailer system is mainly governed by design parameters of tractor trailer system with proper ground surface conditions and loading material. The major reasons which affect stability of tractor trailer, are uneven and different terrain conditions, different types of loading material, overloading and off-centred loading pattern of material, shifting of loads during transportation, high operating speed, improper hitching of trailer with tractor, failure of tractor/trailer component, and unskilled operator without knowledge of carrying loads. A proper recommendation with respect to lighter and heavier material loading pattern in tractor trailer must be worked out in terms of appropriate stake height and loading tonnage keeping in view the design variations, material handled and road and terrain conditions for safe and efficient trailer operation.

Table 4 Percentage of tractor trailer system provided safety devices

Safety Device	% of trailers with safety provisions					
	Single axle trailer			Double axel trailer		
	Haryana	Maharashtra	Average	Haryana	Maharashtra	Average
Braking system (%)	0	0	-	3.57	10.52	7.05
Safety vehicle emblem (%)	46.88	63.41	55.15	92.86	94.74	93.8
Rear light indicators(%)	34.38	43.9	39.14	78.57	84.21	81.39

REFERENCES

Annual report. 2012-13. Ministry of Agriculture, Government of India.

Horst, Wildemann and E. Tobias. 2010. Road Safety in India-An Empirical Survey. 1st Edition: Munich, November. Bridge to India, TCW.

Lande, S. D. 2014. Dynamic Stability of Tractor Trailer System. Unpublished Ph.D. Thesis, Division of Agricultural Engineering, IARI, New Delhi.

Sagi, R., A. Racotch and D. Wolf. 1973. Theoretical Considerations in Placing the Centre of Gravity of Single-Axled Trailers, J. AgricS. Engg. Res., 18, 159-165.

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Effect of Mulches and Drip Irrigation Management on the Quality and Yield of Potato Relating Hydro-Thermal Regime of Soil

by

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Abstract

Utilization of potato as a processed food can help stabilize the potato production as well as its price. Processed food requires certain quality parameters for raw material. With an aim to improve quality parameters of potato, a field study was conducted using mulches and drip irrigation. Three different type of mulches (plastic, bio-degradable and organic) and four irrigation levels were used. The ratio of irrigation water and cumulative pan evaporation (IW/CPE) was fixed 0.6 for low level drip irrigation (LDI), 0.8 for medium level drip irrigation (MDI), 1.0 for high level drip irrigation (HDI) and conventional irrigation was also applied. Plastic mulch showed the best results among other mulches. The highest yield of 33.15 t/ha was obtained under HDI plastic mulch treatment. The average yield of three mulched treatment under drip irrigation was 28.6% higher than the non-mulch drip irrigation treatment. Averaged crop yield (28.99 t/ha) for all the mulched drip irrigated field was 53.5% higher than the conventionally irrigated non-mulched crop (18.88 t/ha). Result also displayed that as compared to non-mulched, plastic & biodegradable mulch treatment increased the minimum soil temperature by 2-3°C and brought it close to the optimum range (10-12°C). The dry matter content of potato was 21.1% and 21.5% in plastic and biodegradable mulch under LDI treatment while it was minimum 14.9% in non-mulched conventional irrigation treatment. Organoleptic observation also showed improvement in the processing quality of potatoes.

Keywords: Mulches, Drip irrigation, Dry matter content, Potato processing quality.

Introduction

Potato rates fourth among the world's agricultural products in production volume. According to World Potato Center's research, worldwide demand for potatoes will exceed than that of rice, wheat, or corn by 2020 (Feng *et al.*, 2011). Potato (*Solanum tuberosum* L.) a rich source of starch, vitamins especially B1 & C and minerals, is one of the rare non-cereal food that can meet the nutritional requirements of the fast growing population particularly in developing countries where it has not yet been adopted as a staple food. The alternative use of potato as processed food can help to stabilize the potato production as well as its prices. The major bottle neck for potato processing is suitability of tuber for processing. Quality requirements of potato tubers for processing depends mainly upon dry matter and reducing sugar content as these determine the yield, texture and quality of processed products. A dry matter content of 18-20% and reducing sugar less than 0.25% is desirable for processing of Potatoes (Verma, 1991). Low night temperature (<10°C) during tuberisation period affects the quality parameters of the crop.

Crop development such as: sprout, growth rate, emergence, and leaf area development are temperature dependent. Yield of potato also depends on temperature, solar radiations, and day length (Harverkort *et al.*, 2004). Accumulation of dry matter content relies on the amount of solar radiation intercepted by crop. Dry matter distribution depends on temperature and photoperiod. Harverkort *et al.*, (2004) also stated that crop may grow only if daily average temperature is in the range of 5-21°C In case daily temperature falls below 5°C, risk of killing by night frost would increase. Yield of potato may increase in temperate climate, provided that water for irrigation is available (Haverkort and Verhagen, 2008).

In the northern parts of India, Potato is grown in winter season only (October-February). In the months of October & November the temperature is favourable but during the months December & January the night temperature (<10°C) leads to low dry matter content (<18%) and high reducing sugar content (>0.25%) of the crop yield, where as if night temperature of 10-12°C is maintained it can improves the quality parameters as well as yield of the crop.

Mulches are known to increase the soil temperature since the sun's energy passes through the mulch and heats the air and soil beneath the mulch directly and then the heat is trapped by the ''greenhouse effect'' (Hu *et al.*, 1995). Mulches promote yields (Feng *et al.*, 2011; Cheng and Zhang, 2000) by decreasing soil bulk density (Anikwe *et al.*, 2007). Mulches greatly retard the loss of moisture from the soil (Gao and Li, 2005). As a result, uniform soil moisture regime can be maintained, and it can also reduce the irrigation frequency.

Maintenance of soil moisture content at higher levels raises the minimum soil temperature (Grewal and Singh, 1974). This task can be better accomplished by drip method of irrigation which supplies water in relatively less quantity but frequently in the root zone only. Moreover, drip irrigation is a proven effective method for high yield of potato (Eldredge *et al.*, 2003; Hou *et al.*, 2010; Kang *et al.*, 2004; Onder *et al.*, 2005; Wang *et al.*, 2003, 2006; Yuan *et al.*, 2003). Accordingly an experiment was designed to modify the hydrothermal soil regime using different types of mulches (plastic, biodegradable and organic) during tubrisation period and drip irrigation for quality and quantity potato production.

Material and Methods

Field studies were undertaken at the Research Farm, Department of Soil and Water Engineering, Punjab Agricultural University, Ludhiana (India). Effect of mulches and drip irrigation on potato (*Solanum tuberosum* L.) production was observed. In the study different type of mulches (plastic, biodegradable and organic) and irrigation levels (LDI, MDI and HDI with 0.6, 0.8 and 1.0 IW/CPE ratio respectively) were applied. Certified seed of potato (*Solanum tuberosum* L) variety Kufri Sutlej was used for the experiment. Three types of mulches i.e. plastic mulch (15 micron thick & 5 m long), biodegradable mulch (15 micron thick & 5 m long) and organic mulch (rice straw) were used to modify the hydrothermal regime of the soil. This experiment had a total of 16 treatments and three replicates for each treatment. Out of a total of 48 plots, 12 plots at random were left un-mulched. A plot measuring 864 m^2 (having 36 plots each measuring 24 m^2) was used for drip irrigated crop and on the other side, a plot measuring 288 m^2 (having 12 plots each measuring 24 m^2) was used for conventionally irrigated crop. The ratio of irrigation water and cumulative pan evaporation (IW/CPE) was fixed 0.6 for low level drip irrigation (LDI), 0.8 for medium level drip irrigation (MDI), 1.0 for high level drip irrigation (HDI) and conventional irrigation. The soil of the experimental area was sandy loam. The initial fertility status of soil (**Table 1**) showed that there was no need to add KCl (Muriate of Potash) to the soil because the soil had sufficient K content.

The recommended dose of N, P, K was 120 kg/ha of Urea, 100 kg of DAP (Diammonium Phosphate)/ha and no potassium. In conventional treatment, 100% of recommended dose of fertilizer was applied i.e. 100% of DAP and 50% of urea at the time of sowing and 50% of urea after 45 days of planting. The crop was conventionally irrigated using siphon tubes having discharge of 1 L/s. The drip irrigation system was tested for design discharge and also to rectify the clogging of emitters if any. The average discharge of emitter was measured to be 2.0 L/hr. In LDI, MDI and HDI treatment, drip irrigation system was operated for 30, 45 and 55 minutes respectively for 12 plots in each treatment. A

Table 1 Initial fertility status of soil

Depth (cm)	N (Kg/ha)	P (Kg/ha)	K (kg/ha)	Organic C (%)	pH	EC (m mhos/cm)
0-15	Medium	11	187.5	0.643	8.3	0.088
15-30	Medium	8	157.5	0.52	8.4	0.072

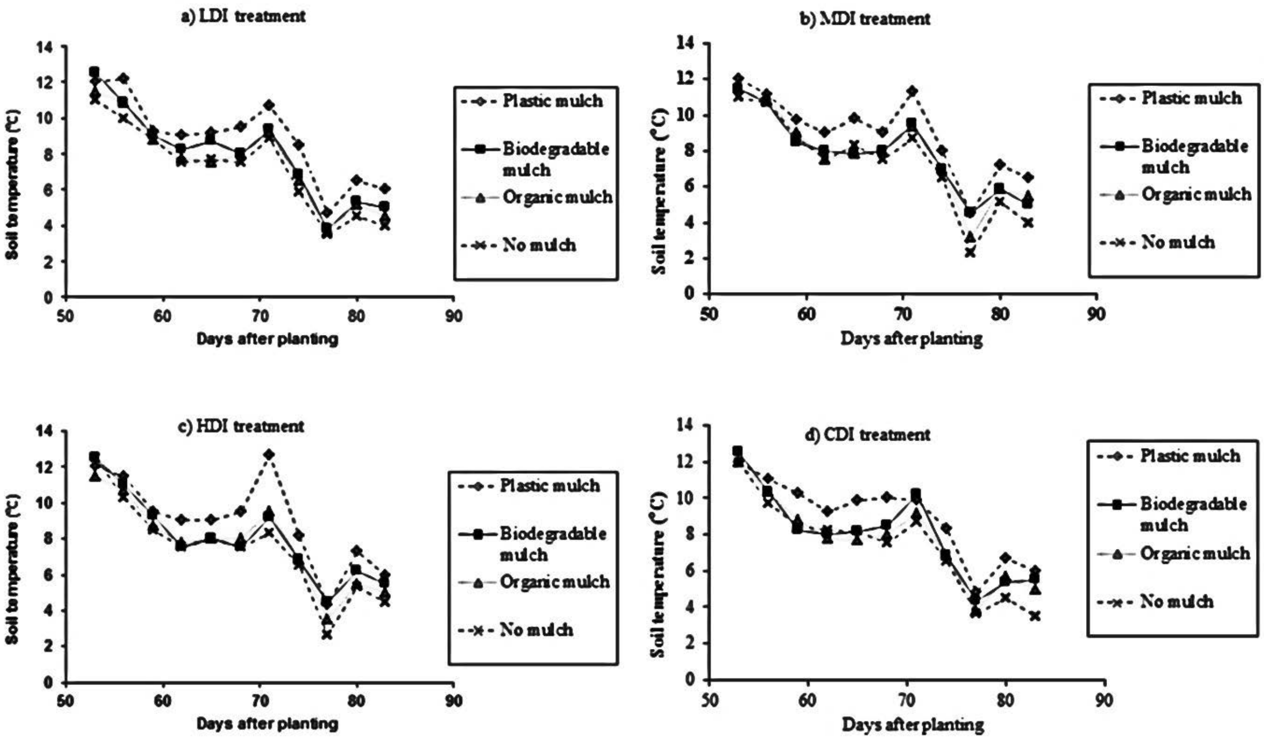

Fig. 1 Variation of minimum soil temperature after planting potato for different mulch treatments

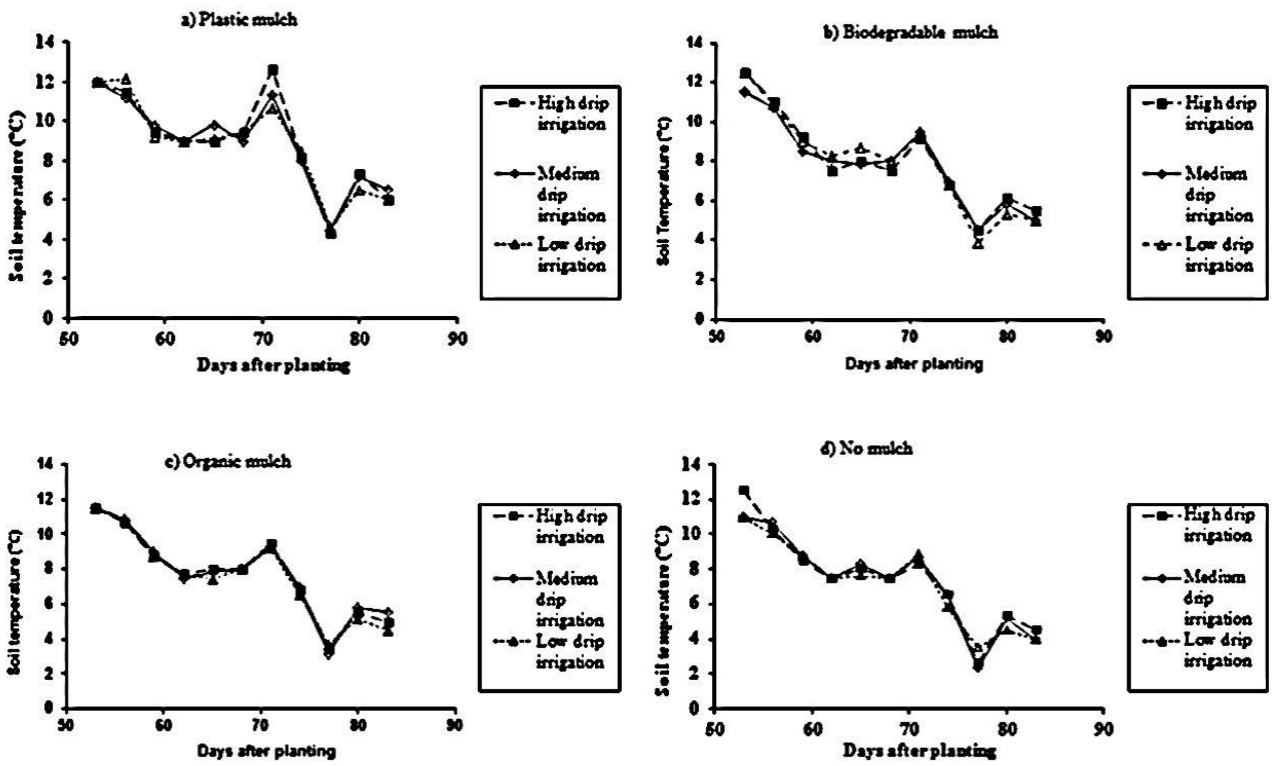

Fig. 2 Effects of different mulches on soil temperature under different irrigation regimes

75% of recommended dose of urea was applied in all the drip irrigated treatments as this dose gave maximum yield when applied with drip irrigation (Chawla, 2001). Whole of DAP and 50% of urea (out of 75% of recommended dose of urea) was applied at the time of sowing. Remaining 50% of urea was applied in 4 equal splits after 45 days of planting at an interval of 10 days.

In order to record daily data of minimum and maximum temperature of soil, soil temperature recording thermometers were installed at a depth of 15 cm both in mulched and un-mulched fields. The minimum temperature was recorded daily at 6.30 a.m. and maximum temperature was recorded at 2.30 p.m. Yield of potato was recorded at the end of the crop season.

Results and Discussion

Effect of Mulches and Drip Irrigation on Soil Temperature

The graphs between minimum soil temperature (three days average) and days after mulches were applied for different type of mulches under different irrigation regimes were plotted in **Figs. 1** and **2**. **Fig. 1** revealed that the minimum soil temperature in all the drip irrigated mulch treatments was always higher than un-mulched drip irrigated treatment. In all the irrigation treatments, the increase of minimum temperature was highest in plastic mulch followed by biodegradable and organic mulch.

Fig. 2 reveals that the rise of temperature was more in case of HDI treatment followed MDI and LDI treatment as the maintenance of soil moisture content at higher levels raises the minimum soil temperature (Grewal and Singh, 1974). The increase in minimum temperature has helped in increasing the yield of crop (mentioned later). The highest yield was obtained from the HDI treatment under plastic mulch due to more favourable soil moisture and soil temperature condition, which produce vigorous growth of crop (Grewal and Singh, 1974).

Effect of Mulches and Drip Irrigation on Yield Attributes

Table 2 displays average fresh tuber yield data for the crop. Result in this table reveals that higher yields were recorded in the drip irrigated plots under mulches than un-mulched plots. The highest yield of 33.15 t/ha was obtained from the HDI drip irrigated plot under plastic mulch; followed by 30.93 t/ha from the same irrigation treatment under biodegradable mulch, and the lowest yield (26.24 t/ha) was observed for un-mulched field under HDI conditions.

Table 2 Comparison of crop yield in reference to irrigation levels and type of mulches

Mulch type	Crop yield (t/ha)				
	Conventional	MDI	HDI	LDI	Mean
Plastic	22.78	29.81	33.15	26.94	28.17
Biodegradable	24.81	27.44	30.93	25.25	27.11
Organic	24.03	29.94	29.63	27.83	27.86
No mulch	18.88	25.74	26.24	15.67	21.63
Mean	22.63	28.23	29.99	23.99	

Table 3 Average yield (t/ha) data on mulch basis

Treatments	Fresh tuber yield (t/ha)		% increase over no mulch	
	Average DI	Conventional	Average DI	Conventional
Plastic mulch	29.97	22.78	32.9	20.7
Biodegradable mulch	27.87	24.81	23.9	31.4
Organic mulch	29.13	24.03	29.2	27.3
Average mulch	28.99	23.87	28.6	26.4
No mulch	22.53	18.88		

The comparison of crop yield for different mulch condition shows highest yield for plastic mulch conditions. Yield of potato averaged for different levels of irrigation was 28.17 t/ha with plastic mulch, 27.11 t/ha with biodegradable mulch, 27.86 t/ha with organic mulch and 21.63 t/ha without mulching. Yield of 18.88 t/ha was obtained from the un-mulched conventionally irrigated treatment which is the lowest. Analysis of yield revealed that the interaction of mulches and drip irrigation had a substantial effect on yield of the crop.

The yield obtained from the drip irrigated plots under mulches was higher than the yield obtained from the conventionally irrigated un-mulched crop. Expected yield of crops lends physical significance to irrigation uniformity measures (Solomon, 1984). The maximum yield obtained in drip irrigation under mulching may be due to the availability of uniform moisture in the soil wetted by drippers, better moisture conservation, proper utilization of nutrients and less weed growth around the potato plant. Similar results were obtained by Jain *et al*., (2001).

Effect of mulches

The average yield data for potato crop under different mulch treatments (**Table 3**) revealed that the yield from the mulched treatments under drip irrigation (DI) was higher compared to mulched treatments under conventional irrigation. The highest average yield 29.97 t/ha was observed in the treatment under plastic mulch with drip irrigation. The increase was 32.9%, 29.2% and 23.9% under drip irrigated plastic, organic and biodegradable mulches over no mulch drip irrigated crop.

The mulched drip irrigated crop

gave comparable yields. The overall mean yield (based on average of all the mulched drip irrigated treatments) was 28.99 t/ha which was 28.6% higher than the un-mulched drip irrigated crop and 53.5% higher than the conventionally irrigated un-mulched crop yield (18.88 t/ha). Statistical analysis showed that there was a significant difference between the yields obtained from the mulched and un-mulched treatments. The differences within the three mulch treatments were non-significant and out of three mulches, plastic mulch was found to be the best to obtain the higher yield.

Effect of drip irrigation

The average yield data of fresh tubers for potato crop under different irrigation treatments has been given in the **Table 4**. The highest yield 31.23 t/ha were obtained from the HDI treatment under mulches against the much less yield of 23.87 t/ha realized for the conventionally irrigated mulched crop, registering an increase of 30.8%. While the overall mean yield (based on average of all the drip irrigated mulched treatments) was 28.99 tq/ha which was 21.4% higher than conventionally irrigated mulched crop. Even the lowest average yield of 26.67 t/ha (LDI) in drip irrigated mulched treatment was more than the un-mulched conventionally irrigated crop.

The drip irrigated un-mulched crop yield of 22.55 t/ha (**Table 3**) was 19.4% higher than conventionally irrigated un-mulched crop yield (18.88 t/ha). Tuber yield obtained from the drip irrigated treatment was significantly different from conventional treatment. Out of the three drip irrigation treatments, HDI was found out to be the best followed by MDI indicating higher tuber yield of fresh tubers against conventionally irrigated grown potato crop.

Grade wise yield of potato crop

The grade wise tuber yield data (**Table 5**) reveals that the HDI treatment had the highest percentage of A grade tubers followed by MDI and LDI treatments. The A grade tubers the all drip irrigated treatments were at par but conventional treatment gave comparatively very small proportion of A grade tubers. All the drip irrigated treatments gave higher percentage of A grade tubers as compare to B grade and C grade tubers while the conventionally irrigated crop gave higher percentage of B grade and C grade tubers. On an average, drip irrigated crop had 47.85% of A grade size, 38.37% of B grade size and only 13.77% of C grade size tubers as compare to 38.73%, 41.98% and 19.20% respectively in conventional treatment. Thus drip irrigation in addition to increase in total yield of potato crop, also improved the quality of the crop in terms of its size. So, the maximum yield of HDI treatment can be attributed to the efficient utilization of applied fertilizer (75% of recommended dose) under drip irrigation as compared to conventional irrigation conditions (100% recommended dose).

Crop yield and water use efficiency

Quantity of water used along with average yield of all mulched yield and water use efficiency (WUE) for various irrigation treatments (**Table 6**) shows that WUE was highest in LDI treatment followed by MDI and

Table 4 Average yield (t/ha) on irrigation basis

Treatments	Fresh tuber yield (t/ha)		% increase over conventional	
	Average mulch	No mulch	Average mulch	No mulch
LDI	26.67	15.67	11.70	-
MDI	29.06	25.74	21.70	36.30
HDI	31.23	26.24	30.80	38.30
Average DI	28.99	22.55	21.40	19.40
Conventional	23.87	18.88		

Table 5 Effect of irrigation regimes on grade wise data of potato crop

Treatment	Grade wise produce*(t/ha)		
	A	B	C
LDI	10.50 (43.73%)	9.6 (40.26%)	3.84 (15.99%)
MDI	13.45 (47.89%)	10.94 (38.95%)	3.69 (13.15%)
HDI	152.63 (51.12%)	108.42 (36.31%)	37.53 (12.56%)
Average DI	13.07 (47.85%)	10.48 (38.37%)	3.76 (13.77%)
Conventional	8.55 (38.73%)	9.27 (41.98%)	4.26 (19.29%)

*A Grade means, mass of potato (mp) > 50g
B Grade, mp 20-50g; C Grade, mp < 20g

Table 6 Yield and quantity of water used and water use efficiency of potato for various treatments

Treatments	Average mulch yield (t/ha)	Water used (cm)	WUE (t/ha/cm)	Water saving over conventional irrigation (%)
LDI	26.67	12.78	2.086	56.3
MDI	29.06	16.04	1.812	45.16
HDI	31.24	19.3	1.618	34.02
Average DI	28.99	16.04	1.807	45.16
Conventional irrigation	23.87	29.25	0.816	

HDI treatment. It was found that the WUE of average of drip irrigated treatments was 2.2 times than that of conventional irrigation.

From yield point, HDI treatment is best and from availability of water point of view, LDI seems to be appropriate method. Water saving in drip irrigation treatments ranged from 34-56% over conventional method of irrigation.

Quality Attributes

Dry matter content

Dry matter content is one of the most important quality parameter, particularly in potato intended for processing. The average dry matter content (%) obtained for potato crop has been given in **Table 7**. It was observed that the optimum dry matter content i.e. 18-20% was observed from all drip irrigated treatments, while lesser dry matter content was observed in conventional irrigation treatment. Even higher dry matter content (21.1% and 21.5%) was obtained in LDI treatment under plastic and organic mulch respectively than the minimum required range. The dry matter contents obtained from conventional irrigated crop under biodegradable and organic mulch were much less (16.3% and 16.4% respectively) than the optimum range. The average lowest value of dry matter content of 14.9% was obtained from no mulch, conventionally irrigated treatment. Statistical analysis clearly showed that the irrigation played significant role in improving the dry matter content of the crop while the mulches had no effect on dry matter content. Also the interaction of irrigation and mulches had insignificant effect on dry matter content.

Processing quality

To test the processing quality of potato crop of mulched and un-mulched treatments, chips were made from all the treatments and were fried as per the standard procedure of making chips from potatoes. Organoleptic evaluation was performed. It is subjective; a sensory judgment based on the experience of the evaluator and was scaled for acceptance. Potato chips obtained from all the mulched treatments were found better in all respects i.e. color, texture, taste and acceptability than the un-mulched treatment. The overall acceptability of all mulched treatments was rating as 7-8 while un-mulched bagged less rating i.e. 6-7 in organoleptic evaluations. Thus the mulches have helped in improving the processing quality of potatoes.

Conclusions

The highest yield of 33.15 t/ha was obtained from the HDI drip irrigated plot under plastic mulch followed by 30.93 t/ha from the same irrigation treatment under biodegradable mulch, while a yield of 18.88 t/ha was obtained from the un-mulched conventionally irrigated treatment. Plastic mulch with drip irrigation resulted into 32.9% increase in yield over un-mulched drip irrigated crop, followed by organic and biodegradable mulch with 29.9% and 23.6% respectively. The average yield of all the three mulch treatments under drip irrigation was 28.6% higher than the no mulch drip irrigation treatment. The average (of all the treatments) mulched drip irrigated crop yield (28.99 t/ha) was 53.5% higher than the conventionally irrigated un-mulched crop (18.88 t/ha).

Plastic mulch and biodegradable mulch increased the minimum soil temperature by 2-3°C and brings it to an optimum that is required for the better growth of crop, which has helped in improving the quality of crop; that is mulches have improved the processing quality of potatoes. The optimum range of 18-20% of dry matter content was obtained from all the drip-irrigated treatments compared to conventional treatment that gave lower dry matter content value. The average lowest dry matter content of 14.9% was obtained from no mulch conventionally irrigated treatment Even the higher dry matter content values of 21.2% in plastic mulch and 21.5% in organic mulch is more than the optimum i.e. 20% organoleptic evaluations have shown good quality chips were obtained from drip irrigated mulched treatments.

Table 7 Statistical analysis of dry matter content

	Conventional	Medium	High	Low	Mean
Plastic	15.3	19.0	20.1	21.1	18.9
Biodegradable	16.3	19.1	18.7	19.9	18.5
Organic	16.4	18.9	18.6	21.5	18.9
No mulch	14.9	15.3	16.3	21.0	16.9
Mean	15.7	17.7	18.5	21.3	

REFERENCES

Anikwe, M. A. N., C. N. Mbah, P. I. Ezeaku and V. N. Onyia. 2007. Tillage and plastic mulcheffects on soil properties and growth and yield of cocoyam (Colocasia esculenta) on an ultisol in southeastern Nigeria. Soil & Tillage Research 93: 264-272.

Chawla, J. K. and N. K. Narda. 2001. Economy in water and fertilizer use in trickle fertigated potato. Irrigation and Drainage 50: 129-37.

Cheng, J. S. and X. X. Zhang. 2000. Study on the ecological effects of plastic mulching on potato in cool and humid highland of Wei'nan county in Gansu province. Chinese Potato 14 (2): 83-84.

Eldredge, E. P., C. C. Shock and L. D. Saunders. 2003. Early and late harvest potato cultivar response to drip irrigation. In: Yada, R.Y. (Ed.), Potatoes - Healthy Food for Humanity. Acta Hort. 619: 233-239.

Feng-Xin Wanga, Xiu-Xia Wua, Clinton C. Shockb, Li-Yun Chua, Xiao-Xiao Gua and Xuan Xuea. 2011. Effects of drip irrigation regimes on potato tuber yield and quality under plastic mulch in arid Northwestern China. Field Crops Research (122): 78-84.

Gao, Y. J. and S. X. Li. 2005. Cause and mechanism of crop yield reduction under straw mulch in dryland. Transactions of the Chinese Society of Agricultural Engineering 21 (7): 15-19.

Grewal, S. S. and N. T. Singh. 1974. Effect of organic mulches on the hydrothermal regime of soil and growth of potato crop in Northern India. Plant and Soil 40: 33-47.

Harverkort, A. J. and A. Verhagen. 2008. Climate change and its repercussions for potato supply chain. Potato Research, 51: 223-237.

Harverkort, A. J., A. Verhagen, C. Grashoff and P. W. J. Vithol. 2004. Potato zoning: a decision support system on expanding the potato industry through agro-ecological zoning using the LINTUL simulation approach. Decision support systems in potato production. Wageningen Academic Publishers.

Hou, X. Y., F. X. Wang, J. J. Han, S. Z. Kang and S. Y. Feng. 2010. Duration of plastic mulch for potato growth under drip irrigation in an arid region of Northwest China. Agric. Forest Meteorol. 150: 115-121.

Kang, Y. H., F. X. Wang, H. J. Liu and B. Z. Yuan. 2004. Potato evapotranspiration and yield under different drip irrigation regimes. Irrigation Sci. 23: 133-143.

Kar, G. and A. Kumar. 2007. Effects of irrigation and straw mulch on water use and tuber yield of potato in eastern India. Agricultural Water Management 94: 109-116.

Onder, S., M. E. Caliskan, D. Onder and S. Caliskan. 2005. Different irrigation methods and water stress effects on potato yield and yield components. Agric. Water Manage. 73: 73-86.

Ramakrishna, A., H. M. Tam, S. P. Wani and T. D. Long. 2006. Effect of mulch on soil temperature, moisture, weed infestation and yield of groundnut in northern Vietnam. Field Crops Research, 95 (2-3): 115-125.

Solomon, K. H. 1984. Yield related interpretations of irrigation uniformity and efficiency measures. Irrigation Science, 5 (3): 161-172.

Verma, S. C. 1991. Potato Processing in India. Technical Bulletin No. 34, CPRI, Shimla, India 34 pp.

Wang, F. X., Y. H. Kang and S. P. Liu. 2003. Plastic mulching effects on potato under drip irrigation and furrow irrigation. Chin. J. Eco-Agric. (Chinese Journal) 11 (4): 99-102.

Wang, F. X., Y. H. Kang and S. P. Liu. 2006. Effect of drip irrigation frequency on soil wetting pattern and potato growth in North China Plain. Agric. Water Manage. 79 (3): 248-264.

Yuan, B. Z., S. Nishiyama and Y. H. Kang. 2003. Effects of different irrigation regimes on the growth and yield of drip-irrigated potato. Agric. Water Manage. 63: 153-167.

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(Continued from 30)

Virmani, S. M. and N. J. Shurpali. 1999. Climate prediction for sustainable production of rainfed groundnuts in SAT: crop establishment risks in groundnut production in the Anantapur region. Technical Manual no. 4. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Madhusudhana. 2010. A Survey on Area, Production and Productivity of Groundnut Crop in India. IOSR Journal of Economics and Finance (IOSR-JEF) e-ISSN: 2321-5933, p-ISSN: 2321-5925. Volume 1.

Jayanthi. 2012. Performance evaluation of Power drawn six row groundnut planters. Journal of Agricultural Engineering Research, 65(2): 57-62.

Sawsan Kamal Eldin Hassan. 2012. "Performance of Animal Drawn Planter on Establishment and Productivity of Groundnut. International Journal of Agricultural Engineering, 4(3). (12-15).

Dahab., M. Hassan. 2013. Development of Animal Drawn Groundnut Planting Machine for Small Holdings Farmers. Journal of Agricultural Engineering Research, 35(2): 27-32.

Guruswamy and N. Kawale. 2006. Energetics of Groundnut Production in Red Soil under Bullock Farms in Raichur Region. Karnataka J. Agric. Sci., 19(3): (641-648).

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Design and Development of a Digital Dynamometer for Manually Operated Agricultural Implements

by

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Abstract

Digital draft measurement of manually operated agricultural implements in the field is an innovative technology to update the traditional draft measurement system. This study was conducted to design and develop of a digital dynamometer to measure the force of manually operated agricultural implements. For manually operated pull type implements such as 2-row granular urea applicator, 4-row granular urea applicator and drum seeder cum granular urea applicator drafts were 52.29 N, 100.92 N, and 89.65 N respectively, when measured by dynamometer and drafts were 55.22 N, 105.03 N, 93.23 N respectively, when measured by traditional method (spring balance). For manually operated push type implements such as BRRI, BARI USG applicator drafts measured by dynamometer were 96.18 N, 90.12 N respectively. The t-test indicated that the draft from dynamometer was significantly uniform than the draft from traditional method for manually operated implements. It was also found that the average draft for manually operated pull type implements such as 2-row granular urea applicator, 4-row granular urea applicator and drum seeder cum granular urea applicator might be 52.29 ±1.13 N, 100.92 ±1.73 N, 89.65 ±1.64 N and 55.21 ±3.95 N, 105.03 ±6.72 N, 93.22 ±5.47 N respectively at 95% confidence level for dynamometer and traditional methods, respectively. The capacity of dynamometer is 392 N with sensitivity 2 mV/V and accuracy is measured in percentage, dynamometer is typically 0.1-1% accurate. Dynamometer was calibrated by the application of known forces and measured the output voltage of the strain gauge bridges. The calibration showed a high degree of linearity between the applied forces and the bridge outputs (R^2 = 0.997). It was found that, the performance of the dynamometer in terms of lower draft force was satisfactory but needs further improvement in terms of higher value of draft force.

Keywords: Load cell, Dynamometer, Agricultural implements, and Draft

Introduction

Manually operated implements are extensively used in Bangladesh for various farm operations starting from seedbed preparation to post-harvest operations. There is no available information about how much energy required in manually operated machine available in Bangladesh. Draft requirement will often dictate the size of power on particular farm activities. Since the power unit represents a major capital investment, a better understanding of draft requirements can aid machinery management system. Energy management of agricultural machinery will also be increasingly important in the future. Draft requirements will also be required for energy management. The availability of draft requirement data of manually operated agricultural machinery or implements is an important factor in selecting suitable implements for a particular farming situation. Farm managers and consultants also use draft and power requirement data of implements to determine correctly the proper size of implements or machinery.

Presently, there is a shortage of precise data on draft requirements of manually operated agricultural implements in Bangladesh. In Bangladesh most of manually operated agricultural machinery operation both pushing and pulling forces were measured by using tension spring balance. It does not give the accurate result because tension spring balance gives the tensile force that means pulling force. It was observed that the direction of resultant force of all pull type implement is upward and the direction of resultant force of push type implement is downward. Many studies have been reported to measure draft of manually operated push type implements by spring balance (Ahmed *et al*., 2014) as shown in **Fig. 1**.

In **Fig. 1**, the pushing forces were measured using tension spring balance by different researchers. As time progressed, the periodic updating of data acquisition systems on draft is required. New information is available from research to update the draft measurement system.

Recent innovation in electronic data acquisition systems have made measurements of draft easier with respect to arduous environmental conditions experienced in the field. In order to measure draft requirements for an implement the system must be able to measure force in the field without interference from dust, moisture, or vibration. The ease of making draft measurements has been enhanced through the use of strain gage load cells.

These devices also made it possible to record data at a high rate, making large data bases possible for a more accurate prediction. A literature survey showed that techniques such as a three-point hitch dynamometer is available to measure draught force and drawbar power requirements for mounted implements (Lotfi *et al*., 2007 and Keen *et al*., 2009). Dynamometer was calibrated by the application of known forces and measuring the output voltage of the strain gauge bridges. The calibration showed a high degree of linearity between the applied forces and the bridge outputs (R^2 = 0.996). A simple and easy technique to measure the traction force by hydraulic three point hitch dynamometer was developed (Tenu *et al*.,2012). Yadav *et al*., (2007) studied a Novatech load cell with digital indicator to measure the push-pull force of paddy transplanter.

The main purpose of this study was to develop a digital dynamometer for manually operated agricultural implements by using load cell and to determine pull and push forces and to compare the draft forces measured by spring balance and the developed dynamometer.

Materials and Methods

Design and Development of a Digital Dynamometer

Design of a load cell

Load cell is essentially consists of strain gauge. Cu, Ni, Al alloy are

Fig. 1 Measurement of pushing force using spring balance

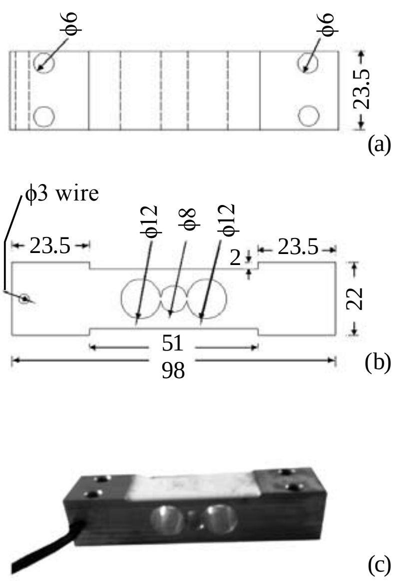

Fig. 2 (a) Top view (b) Front view (c) Pictorial view of load cell

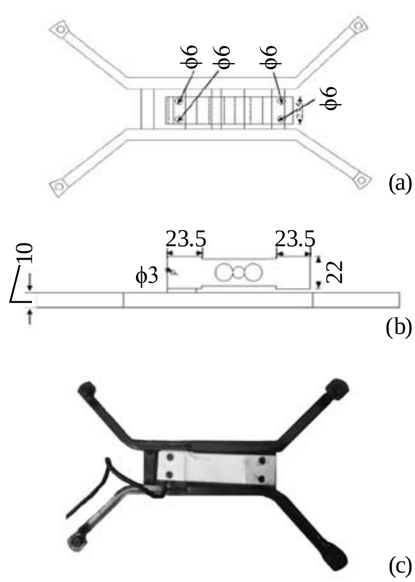

Fig. 3 (a) Top view (b) Front view (c) Pictorial of a frame for load cell

commonly used in strain gauge construction as the resistance change of the foil is virtually proportional to the applied strain. The design and construction of load cell are shown in **Fig. 2** (a)-(c), respectively. All dimensions are in mm.

Design of a frame for load cell

A frame of MS square pipe was attached with load cell to apply the force on it. For operational comfort it can be used in dynamometer. In **Fig. 3** (a)-(c) show the design and construction of frame for placing load cell on it (dimensions are in mm).

Design of U-shaped frame for adjusting dynamometer with implement

A U-shaped MS flat bar was attached with the dynamometer for the adjustment with the handle of implement. Two bores were drilled in U-shaped MS bar to attach the load cell and six pairs were drilled to attach dynamometer with the handle of machine or equipment. In **Fig. 4** (a)-(c) show the design and construction of U-shaped frame with load cell and all dimensions are in mm.

Power requirement

AC 110V-230V and DC 10V rechargeable battery is required to operate the dynamometer.

Strain gauge in load cell

A load cell is a transducer that is used to convert a force into electrical signal. The flow diagram of dynamometer is shown in **Fig. 5**.

The system block diagram of dynamometer is shown in **Fig. 6**.

Load cell measures the deformation and convert it into equivalent electrical signal. Then amplifier amplifies the electrical signal. Analog to digital converter with a microcontroller (ADuC874) is used to convert the analog electrical signal to digital signal. Then a LCD display and a key pad are integrated with microcontroller and the digital value of force is displayed. Strain gauge under different conditions is shown in **Fig. 7**.

Strain gauge under tension, resistance goes up. Strain gauge under compression, resistance goes down. The gauges were attached to the object by a suitable adhesive. As the object is deformed, causing its electrical resistance to change. The changes of resistance were measured using a Wheatstone bridge principle.

Dynamometer Design is based on Wheatstone bridge circuit

Circuit diagram of Wheatstone bridge principle as used in dynamometer is shown in **Fig. 8**.

In order to demonstrate how a Wheatstone bridge operates in load cell, a voltage scale has been drawn

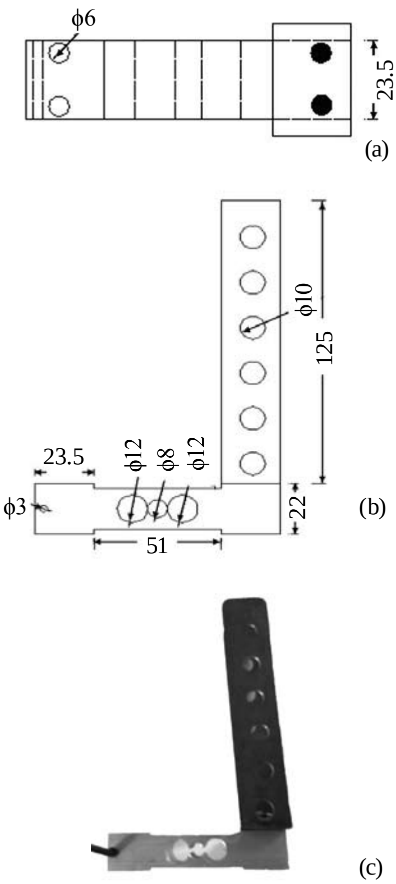

Fig. 4 (a) Top view (b) Front view (c) Pictorial view of U-shaped frame with load cell

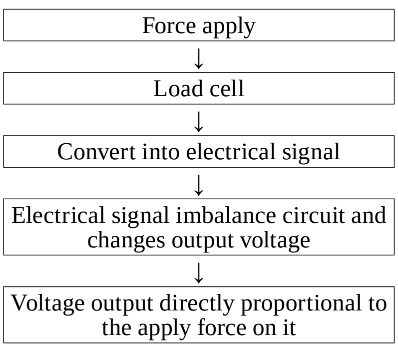

Fig. 5 Flow diagram of the working principle of dynamometer

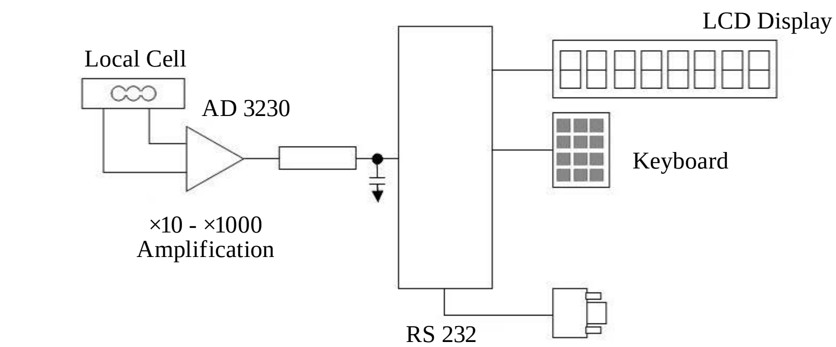

Fig. 6 System block diagram of dynamometer

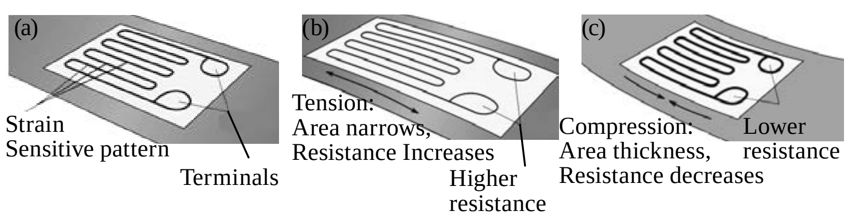

Fig. 7 Strain gauge under different conditions (a) Normal (b) Tension (c) Compression

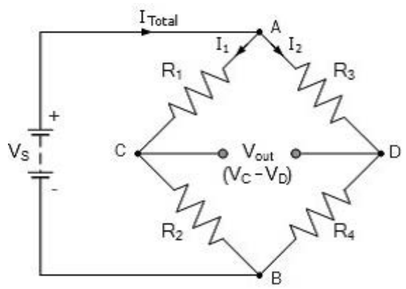

Fig. 8 Wheatstone bridge circuit diagram in dynamometer

Fig. 9 Force measurement in the field by dynamometer

Fig. 10 Force measurement in the field by spring balance in traditional method

at points C and D of **Fig. 8**. Assume that R_1 is a bonded gage. If R_1 is now stretched so that its resistance increases by one unit (+ ΔR), the voltage at point C will be increased from zero to plus one unit of voltage (+ ΔV), and there will be a voltage difference of one unit between C and D that will give rise to a current through D.

The output voltage of this type of Wheatstone circuit can be measured using Eq. 1.

$$V_o = \left[\frac{R_2}{R_1 + R_2} - \frac{R_4}{R_3 + R_4}\right] \times V_S$$

....(Eq. 1)

Sensitivity of the instrument is important. It is always expressed in mV/V. A bridge 2 mV/V sensitivity will deliver 2 mV if the measurement is at full-scale and the bridge is excited with 1V.

Calibration of dynamometer

Dynamometer was calibrated by measuring output voltage. The different values of known forces were applied on load cell and output voltage for these forces can be measured.

Draft Measurement

Force measured by digital dynamometer

The dynamometer was fitted with the handle to press force on dynamometer as shown in **Fig. 9**. The values of the forces digitally appeared in display window. Data were read and recorded by a camera (5xZoom, 14.1 mega pixel, Sony) in video mode.

Force Measured by Spring Balance in Traditional Method

Spring balance was fixed in the implement and pulled the applicator as shown in **Fig. 10**. Data were read and recorded by a camera (5xZoom, 14.1 mega pixel, Sony) in video mode. The video was played by KMplayer and captured the slides of video to find the force in various time.

Flow diagram of data collection from video is shown in **Fig. 11**.

The captured slides of forces with various time are shown in **Fig. 12**.

Video record of digital dynamometer and spring balance during operation
↓
Load of video from camera to computer
↓
Play with KMplayer
↓
Click capture
↓
Advance capture of video
↓
Continuously capture
↓
Start to capture
↓
Restore of capture view
↓
Observe the dynamometer reading from capture slides

Fig. 11 Flow diagram of data collection from video

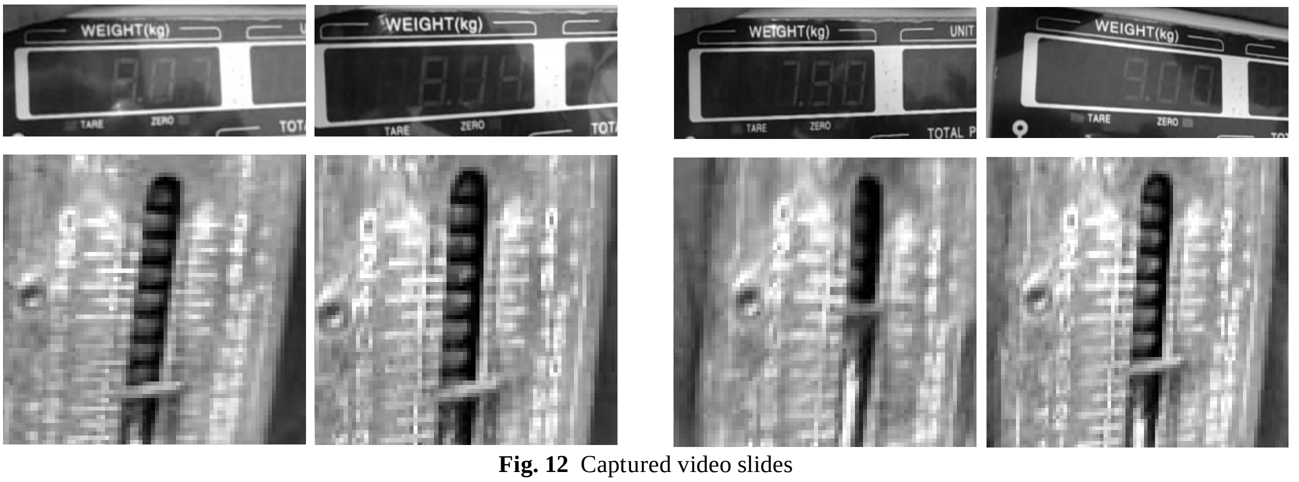

Fig. 12 Captured video slides

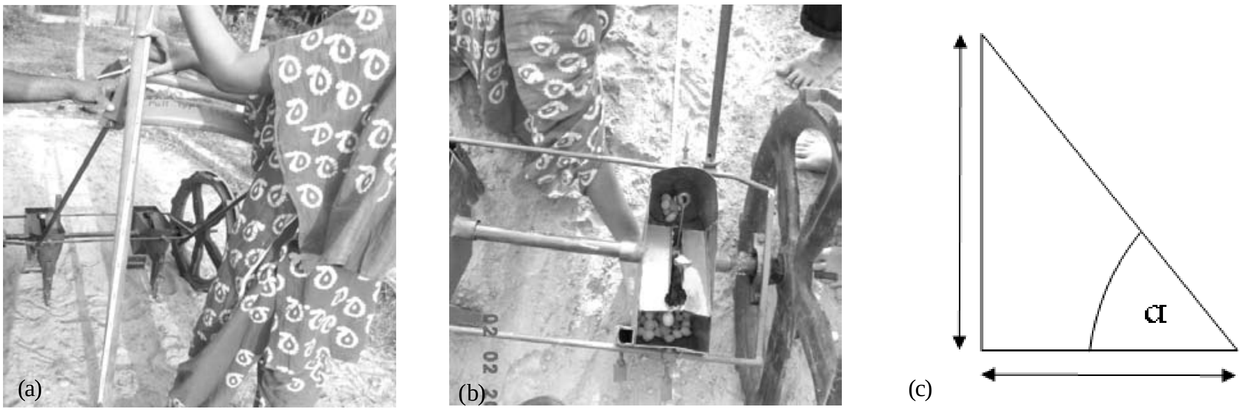

Fig. 13 Measurement of (a) height (b) length (c) angle of triangle

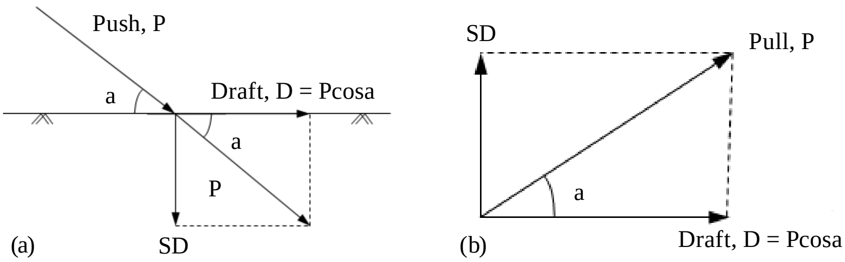

Fig. 14 Draft measurement of (a) Push and (b) Pull type implements

Fig. 15 Developed dynamometer

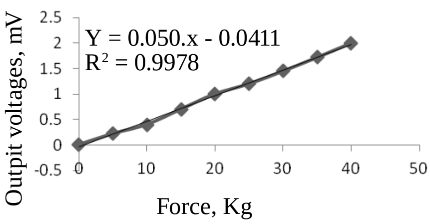

Fig. 16 Calibration of dynamometer

Calculation of draft

Draft may be defined as the horizontal component of pull parallel to the line of motion. Mathematically,

Draft = P cosα

Draft = mg cosα

where,

P = pulling or pushing force in, N

α = Angle between pull or push with ground

Angle measurement

The height and horizontal length of pulling and pushing handle were measured to determine pulling or pushing angle as shown in **Fig. 13**. By measuring the height and length of a triangle, angle of pull or push easily determined using the following formula.

Pulling or pushing angle, a = tan^{-1} Height of triangle / Length of triangle

The analysis of forces in pushing and pulling implements are shown in **Fig. 14**.

Descriptive analysis of Draft

Descriptive analysis is performed by Microsoft Excel 2007.

Comparison of Draft Measured by Dynamometer and Spring Balance

The comparison of draft measurement is done by t-test. The t-test was done by Microsoft Excel. Hypothesis was there is no difference between drafts from both methods.

i.e., H_0: $\mu_{SB} = \mu_D$

H_1: $\mu_{SB} > \mu_D$ or H_1: $\mu_{SB} < \mu_D$

where,

μ_{SB} = draft from spring balance; μ_D = draft from dynamometer

It was analyzed at α% level of significance for one-tailed test

Results and Discussion

Development of a Digital Dynamometer

Dynamometer was fabricated at the engineering workshop of the Department of Farm Power and Machinery, Bangladesh Agricultural University with the help of S.R instrument, Dhaka. The construction cost of dynamometer is Tk. 3,500. The dynamometer is powered by AC 110V-230V and DC 10V which is supplied from rechargeable battery. It was made with strain gauges. It is able to measure forces of the implements and appear data in digital display. The capacity of dynamometer is 40 kg, sensitivity 2 mV/V and accuracy is measured in percentage. The pictorial view of developed dynamometer is shown in **Fig. 15**.

Dynamometer was calibrated using known forces and measured the output voltage of the strain gauge bridges. The calibration showed a high degree of linearity between the applied forces and the bridge outputs (R^2 = 0.997). The calibration result of dynamometer is shown in **Fig. 16**. It is indicated that dynamometer measures draft accurately. Force in **Fig. 16** should be converted to Newton (N).

Draft Measurement of Manually Operated Pull Type Implements

For draft measurement, pulling force and pulling angle were calculated. The pulling angle for 2-row, 4-row USG applicator and drum seeder cum granular urea applicator were 53°, 40°, and 40° respectively. The force required to operate the pull type applicators were taken from captured video slides for dynamometer and traditional method. Then the drafts were calculated. For measuring the average draft of applicators, twenty-one data was taken. Descriptive statistics was tabulated in **Tables 1**, **2**, and **3**.

From the above **Tables** Mean, Median, and Mode of drafts were very close to each other in dynamometer that indicate the drafts were quite uniform for dynamometer than traditional method. Standard errors, standard deviation, variance for dynamometer were less than traditional method. So dynamometer is able to measure draft uniformly and accurately.

Table 1 Descriptive statistics of draft measurement of 2-row granular Urea Applicator

Parameters	Traditional method	Dynamometer
Mean	55.22	52.29
Standard Error	1.89	0.54
Median	56.08	53.14
Mode	56.08	50.18
Standard Deviation	8.68	2.49
Sample Variance	75.47	6.20
Kurtosis	4.57	-0.64
Skewness	-2.00	0.05
Range	35.42	8.84
Minimum	29.52	47.23
Maximum	64.94	56.07
Count	21	21
Confidence Level (95.0%)	3.95	1.13

Table 2 Descriptive statistics of draft measurement of 4-row granular Urea Applicator

Parameters	Traditional method	Dynamometer
Mean	105.03	100.92
Standard Error	3.22	0.83
Median	105.21	101.45
Mode	120.23	105.21
Standard Deviation	14.76	3.80
Sample Variance	218.05	14.50
Kurtosis	-1.10	-1.01
Skewness	-0.11	-0.32
Range	45.09	11.27
Minimum	82.66	93.94
Maximum	127.75	105.21
Count	21	21
Confidence Level (95.0%)	6.72	1.73

Draft Measurement for Push Type Implements

For draft measurement, pushing force and pushing angle were calculated. The pushing angle for both BARI and BRRI USG applicator was 36°. The pushing forces of these types of applicators were taken in the field by captured video slides. The descriptive statistics are shown in **Tables 4** and **5**.

Tables 4 and **5** also showed that standard error, standard deviation, variance of dynamometer were less than traditional method for push type implements. So draft measured by dynamometer was standard and accurate.

Comparison of Draft Measured by Dynamometer and Traditional method

t-Test of Pull type manually operated agricultural implements

The average drafts of 2-row,

Table 3 Descriptive statistics of draft measurement of Drum seeder cum granular Urea Applicator

Parameters	Traditional method	Dynamometer
Mean	93.22	89.65
Standard Error	2.62	0.79
Median	90.18	90.18
Mode	90.18	90.18
Standard Deviation	12.03	3.62
Sample Variance	144.90	13.11
Kurtosis	-0.81	0.58
Skewness	0.21	-0.06
Range	41.33	15.04
Minimum	71.4	82.66
Maximum	112.73	97.7
Count	21	21
Confidence Level (95.0%)	5.47	1.64

Table 4 Descriptive statistics of draft of BRRI USG applicator by Dynamometer

Parameters	Traditional method	Dynamometer
Mean	105.23	96.18
Standard Error	9.5	1.70
Median	107.25	95.24
Mode	102.5	95.24
Standard Deviation	14.75	7.82
Sample Variance	95.23	61.27
Kurtosis	-0.28	0.24
Skewness	-0.24	0.10
Range	49.68	31.74
Minimum	75.77	79.37
Maximum	125.45	111.11
Count	21	21
Confidence Level (95.0%)	6.75	3.56

Table 5 Descriptive statistics of draft of BARI USG applicator by Dynamometer

Parameters	Traditional method	Dynamometer
Mean	105.57	90.12
Standard Error	8.65	1.37
Median	103.35	88.4
Mode	102.65	88.4
Standard Deviation	9.35	6.30
Sample Variance	75.48	39.69
Kurtosis	-0.25	-0.08
Skewness	-0.10	0.23
Range	36.62	24.11
Minimum	78.85	80.36
Maximum	115.47	104.47
Count	21	21
Confidence Level (95.0%)	6.37	2.86

4-row USG applicators and drum seeder cum granular urea applicator for using spring balance and Dynamometer were 55.22N, 105.03N, 93.23N and 52.29N, 100.92N, 89.65N, respectively. The t-test of draft was performed by Microsoft Excel on assuming that there was no difference of draft from spring balance and dynamometer. That means, H_0: $\mu_{SB} = \mu_D$ The test was performed at 5% level of significance for one-tailed. The result of t-test is presented in **Tables 6**, **7** and **8**. It was observed that the calculated value of t (1.48), (1.24) and (1.31) for 2-row, 4-row USG applicators and drum seeder cum granular urea applicator were greater than the tabulated value of t (1.30), (1.19) and (1.19) at 5% level of significance. It was indicated that the hypothesis was rejected. That means there is a significant difference between the draft obtained from using spring balance and Dynamometer. These results indicated that the draft from Dynamometer was lower than the draft from spring balance. Draft measurement by Dynamometer was significantly uniform and variance was lower than spring balance method.

Comparison of Draft of Pull Type Implements

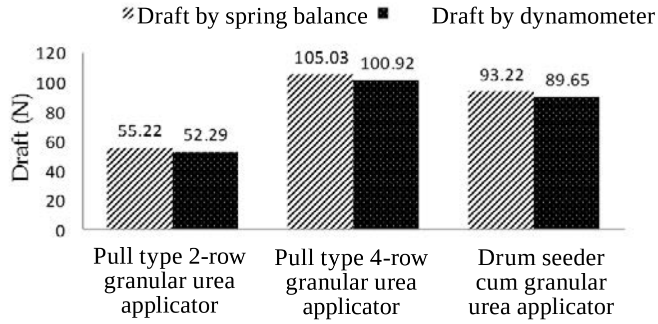

Fig. 17 Comparison of draft of pull type implements

When the draft was measured by the dynamometer, it was less than spring balance as shown in **Fig. 17**.

For same implement and same working conditions, the value of draft measured by dynamometer found to be less than the spring balance. It indicates that there was less error in draft measured by dynamometer.

Conclusions

Dynamometer is simple in construction and its operation is very easy. This dynamometer can measure draft for both pull and push type manually operated agricultural implements with high accuracy 0.1-1% and sensitivity 2 mV/V. This dynamometer can be used for lower draft force and capacity of dynamometer up to 40 kg. Draft can be measured accurately by dynamometer than traditional method.

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REFERENCES

Ahamed, M. S., A. T. M. Ziauddin and R. I. Sarker. 2014. Design of improved urea supper granule ap-

Table 6 t-test result of draft of 2-row granular urea applicator

t-Test: Two-Sample Assuming Equal Variances

Parameter	Traditional method	Dynamometer
Mean	55.22	52.29
Variance	75.47	6.2
Observations	21	21
Pooled Variance	40.84	
Hypothesized Mean Difference	0	
Df	40	
t Stat	1.48	
P(T<=t) one-tail	0.07	
t Critical one-tail	1.30	
P(T<=t) two-tail	0.14	
t Critical two-tail	1.68	

Table 7 t-test result of draft of 4-row granular urea applicator

t-Test: Two-Sample Assuming Equal Variances

Parameter	Traditional method	Dynamometer
Mean	105.03	100.92
Variance	218.05	14.50
Observations	21	21
Pooled Variance	116.2825	
Hypothesized Mean Difference	0	
Df	40	
t Stat	1.24	
P(T<=t) one-tail	0.11	
t Critical one-tail	1.19	
P(T<=t) two-tail	0.22	
t Critical two-tail	1.58	

Table 8 t-test result of draft of Drum Seeder cum Granular Urea Applicator

t-Test: Two-Sample Assuming Equal Variances

Parameter	Traditional method	Dynamometer
Mean	93.23	89.65
Variance	144.90	13.11
Observations	21	21
Pooled Variance	79.07	
Hypothesized Mean Difference	0	
Df	40	
t Stat	1.31	
P(T<=t) one-tail	0.09	
t Critical one-tail	1.19	
P(T<=t) two-tail	0.19	
t Critical two-tail	1.58	

plicator. International Journal of Applied Science and Engineering Research, 3 (1): 99-106.

Keen, A., M. D. Gholkar, J. Ward, V. Salokhe and P. Soni. 2009. Force measurement between a tractor and a three point linkage mounted cultivation implement. Proceedings of the 10th International Agricultural Engineering Conference, Bangkok, Thailand, 7-10 December; 2009.

Lotfi, D., A. Hemmat and M. R. A. Sarraf. 2007. Development and evaluation of a three- point hitch dynamometer and a fifth wheel for mounted implement draft and tractor speed measurements. Journal of Science and Technology of Agriculture and Natural Resources, 11 (1(A)): 147-163.

Yadav, R., P. Mital, S. P. Shukla and S. Pund. 2007. Ergonomic evaluation of manually operated six-row paddy transplanter. International Agricultural Engineering Journal, 16 (3/4): 147-157.

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Development and Evaluation of Impact and Shear Type Tamarind Deseeder

by

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Abstract

The tamarind processing involves the following unit operations after harvest such as drying, dehulling, drying, deseeding, shaping into thin cake and storage. Deseeding is one of the important unit operations in tamarind processing which is being predominantly done manually. The conventional method followed is crude, unhygienic, labour intensive and time consuming process. Hence, a simple and low weight power operated machine was developed at the Department of Food and Agricultural Process Engineering, Tamil Nadu Agricultural University, Coimbatore to deseed the tamarind fruits with the principle of exerting impact load and simultaneous shear over the fruit by studs mounted rotor assembly encased with sieve. The machine was evaluated for its performance in terms of deseeding efficiency at different levels of factors: moisture content of tamarind fruit (25%, 23.5% and 22% db.), rotor peripheral speed (1.1, 1.3 and 1.6 m/s) and cylindrical sieve (made up of cylindrical rods, square bars and oblong sieve). Comparing the maximum deseeding efficiency among different tested combinations, the maximum efficiency was achieved at the peripheral speed of 1.3 m/s encased with the cylindrical sieve made up of oblong sheet at the moisture content of 23.5%.

The maximum deseeding efficiency achieved at this combination was 82%.

The capacity of the machine was 60 kg/h.

Introduction

Tamarind (*Tamarindus indica* L.) belongs to the family of Fabaceae (Leguminosae). Tamarind is cultivated in 54 countries of the world, out of which Asian and American continents are the major producers of tamarind. In most of the countries, tamarind is a subsistence tree crop mostly meeting local demands. The major product is the fruit, which is used for culinary purposes while the seed is the main component used in industrial applications. On an average, tamarind pod contains 55% pulp, 34% seeds and 11% shell and fibres (Rao and Mathew, 2001). The pods are oblong or sausage shaped, curved or straight, with rounded ends. The shell is brittle in nature and is filled with pulp. The pulp is analogous to human finger in shape connected by a series of compartments and each compartment is possessed of a single seed. The pulp is constricted between compartments. The outer surface of the pulp has three tough branched fibres from the base to the apex to strengthen the compartments (Gunasena and Hughes, 2000).

After harvesting, the fruit is dried and shell is removed from the pulp by beating the fruit with sticks. The pulp along with seed is bagged and stored. During demand, the fruit is deseeded and sold in the market. Seed removal is an important unit operation in tamarind processing since other forms of value added products such as tamarind concentrate, powder and biocolour extraction are possible only after deseeding. The present prevailing practice of tamarind deseeding is to beat the fruits manually with a hammer or wooden mallet by women labourers. In southern parts of India, a long needle which is used to stitch gunny bags is used to deseed tamarind. Individual compartments of tamarind fruit is pierced by the needle to create failure for facilitating seed removal process. In southeast, tamarind is deseeded by the process of hand pounding in which a stone mortar is sprayed with oil generally of castor oil and a wooden pestle is used to exert impact load over the fruits. In some parts of Tamilnadu, knife is used to deseed. The conventional methods followed are crude, unhygienic, labour intensive and time consuming process. This drudgery can be alleviated by introducing a deseeder for tamarind.

Fig. 1 Rotor shaft with auger and stud assembly

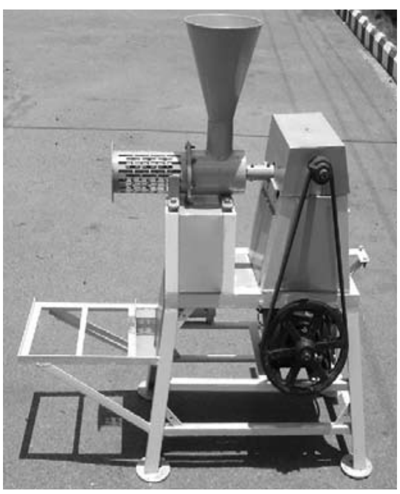


Fig. 2 Tamarind Deseeder

There are two methods available in seed removal. They are wet and dry methods. In wet method, the shell is removed manually, followed by agitation of the seeds in water in order to disperse the pulp and separate it from the seeds. Benero *et al.* (1972) reported the mechanical extraction of tamarind pulp after dilution with water (1:2). The dilution produced slurry that allowed continuous operation of the pulping line. Mosqueda (1980) described a process for extraction of pulp in which pre-fermentation of pulp in 1:2 (fruit: water) dilution prior to pulping and heat treatment was used. The industrial process for the manufacture of tamarind juice concentrate in India is also based on extraction of pulp with boiling water (Salunkhe *et al.*, 1995). In dry method of seed removal, water is not used and fruits are subjected to drying process before deseeding to mitigate the stickiness. Babu *et al.* (1999) developed the pulp-squeezing unit consisted of a serrated roller mounted on a mild steel (MS) frame. Adjoining to the roller, stationery rasp bar was provided. The tamarind was passed through the clearance between serrated roller and rasp bar to separate seed out of pulp. The mechanical machine was stopped intermittently to scrap away the deposits of tamarind pulp over the mechanism. Shalini *et al.* (2007) studied three different mechanisms such as two wooden identical plain rollers, wooden rasp-bar drum with concave and metal rasp-bar drum with concave to shear and squeeze the pulp for the removal of seeds. The end-product out of the machines was collapsed and the compartmental arrangement of tamarind was detached.

Even though a few mechanisms were studied so far, they had their own limitations in popularizing among the farming community. These machines cannot be operated continuously because of the sticky nature of tamarinds with the mechanisms adopted and the collapsed end product is sold at throw-away prices. Final output of the existing deseeding machines is a mixture of pulp and seed and separation of the seed out of pulp is again laborious and time consuming. With the intention of alleviating these constraints, a tamarind deseeder was developed and evaluated at the Department of Food & Agricultural Process Engineering, Tamil Nadu Agricultural University, Coimbatore by optimizing process parameters like materials used for fabrication, clearance and speed of the unit.

Materials and Methods

Development of Tamarind Deseeder

The fabricated tamarind deseeder (**Fig. 2**) consisted of feed hopper, rotor shaft, screw auger, deseeding unit, power transmission system, motor and frame.

Feed hopper

A cone shaped feed hopper was fabricated to feed the dried tamarind fruit into the deseeding unit. The diameter at the top and bottom of the hopper was 225 and 72 mm, respectively. The hopper was welded at the top end of a 5 mm thick 'C' type mild steel pipe behind which a 38 mm thick circular plate of 102 mm outer diameter and 25 mm inner diameter was welded. The inner diameter of the circular plate was plugged with 25.4 mm diameter ball bearing to accommodate rotor shaft in order to connect with the transmission system.

Rotor shaft

The rotor shaft (**Fig. 1**) is an important component of the deseeding machine. It consisted of helical blades (screw auger) to convey the feed and studs of 25 × 6 mm were welded on the rotor in zigzag manner for imparting impact load over the fruits. One end of the rotor shaft was coupled to the power transmission system supported suitably on

25.4 mm ball bearing. A rotor shaft of 400 mm length and 25.4 mm in diameter was used.

Screw auger

The screw auger was made out of 4 mm thick and 102 mm diameter of mild steel round flat sheets by cutting and stretching it suitably. The diameter and pitch of the auger was 90 mm and 35 mm, respectively.

Deseeding unit

The seed separation unit was meant for separating the seeds from the fruit. The main components of the deseeding unit are studs on the rotor and oblong sieve. Studs of 25.4 mm length and 6 mm diameter were provided helically on a mild steel rotor. A clearance of 13 mm was kept between the oblong sieve and the tip of studs. An oblong sieve of size 20 × 5 mm was rolled and made as a cylinder of 102 mm diameter and 230 mm length. It was welded at both the sides with a flange having inner diameter of 100 mm and outer diameter of 150 mm to rest hopper assembly over it. Thickness of the flange was 4 mm. In this section, the fruits were subjected to impact load by the studs to break open the fruits and shearing action by the same studs over the fruits to push the seeds out of the oblong sieve.

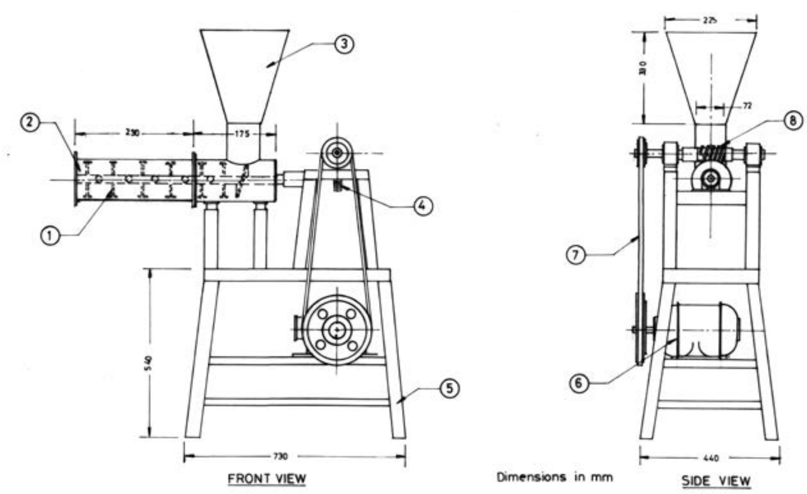
Power Transmission System

Optimization of rotor speed is essential for efficient separation of seeds from the failed fruits. Preliminary tests conducted with the developed unit by coupling the unit to a variable speed motor showed that a rotor shaft speed of 250 rpm yielded better results. Hence, the following components were used in the unit in order to transfer required speed; these are, Sub frame, Pulleys and V-belt and Worm gear and pinion

Two frames of trapezoidal shape were provided over the main frame. The dimensions of the trapezoidal frame were 185 mm at the top and 290 mm at the bottom and 300 mm in height. Counter-shaft with pinion was mounted on it with the help of two ball bearings. These two trapezoidal frames were braced at 250 mm height on which two ball bearings were mounted to provide support to the rotary shaft connected countershaft mounted with worm gear. The material used for the fabrication of frame was L-angle mild steel size of 40 × 40 × 6 mm. The frames were welded to the main frame to provide rigidity and to withstand vibration during operation.

For the tamarind deseeding experiments, the speed of rotor shaft was also considered as one of the variables. Hence, different size single 'B' groove pulleys were used both on motor shaft and on counter shaft to get different rotor shaft speeds. The pulley at the motor shaft was changed to get the desirable speeds of the rotor shaft. Different lengths of V-belts were used to transmit the power from the motor to the counter shaft.

A reduction gear system was used to reduce the motor speed from 1,440 rpm to the range of 200 to 300 rpm required for the experiment. A worm gear and pinion was selected to make the unit more compact and transmit the power smoothly. The selected worm gear and pinion resulted 16 times speed reduction. The worm gear was mounted on the counter shaft which in turn connected to the rotor shaft. The rotor shaft was supported on either side with ball bearings and the whole assembly was mounted on the braces welded on the sub frames. The pinion was mounted on a counter shaft (driving) and was placed exactly on the top of worm gear wheel. Two ball bearings were also provided on either side of the pinion mounted counter shaft, to give free rotation to the pinion. The bearings were fixed on the sub frame. This speed reduction system arrangement allows the motor to be housed below this assembly and thereby reduced the effective space required for the fabrication of the whole machine. A single hp single phase electric motor of 1,440 rpm was selected.



1	STUD	5	FRAME
2	OBLONG SIEVE (20x5mm)	6	MOTOR
3	HOPPER	7	BELT DRIVE
4	PINION	8	WORM GEAR

Fig. 3 Tamarind Deseeder

Fig. 4 Cylindrical sieves made up of square bars, sheet having oblong hole and cylindrical rods

Frame

The trapezoidal frame was made up of mild steel L-angle section of size 40 × 40 × 6 mm. The size of the frame at the top was 600 × 400 mm and at the bottom 730 × 440 mm. The height of the frame was 540 mm. The frame is well braced to provide rigidity to mount and support other parts of the machine and to withstand vibrations during operation. Two dimensional views of tamarind deseeder are given in **Fig. 3**.

Three different sieves (**Fig. 4**) were fabricated for finding deseeding efficiency. They were, sieves made up of cylindrical rods, sieve made up of square bars and sieve made up of a sheet having oblong holes.

Sieve made up of cylindrical rods

Thirteen numbers of cylindrical rods of 6 mm diameter and 230 mm length were welded with 152 mm diameter flange whose inner diameter was 102 mm to make a concave at an interval of 6 mm. The remaining arc length of the flange was welded with 3 mm thick MS sheet over the concave.

Sieve made up of square bars

Thirteen square bars of 6 × 6 mm and length of 230 mm were welded with a flange of 152 mm outer diameter and 102 mm of inner diameter. The interval between the square rods was maintained at 6 mm.

Sieve made up of a sheet having oblong hole

A mild steel sheet having 20 × 5 mm oblong hole was converted into a cylinder of 230 mm height and 102 mm diameter. It was welded with a flange of 102 mm inner diameter and 152 mm outer diameter.

Rotational speed of shaft

A variable speed motor (Powermag Control Systems Private Limited, Coimbatore) was coupled with a 1.0 hp, -three phase motor to vary the rotational speed of the shaft. The machine was tested at 200 (1.1 m/s), 250 (1.3 m/s) and 300 (1.6 m/s) rpm levels.

Evaluation of Tamarind Deseeder

The developed tamarind deseeder was tested for its performance under three variable conditions. Three different sieves made of sheet having oblong perforations (S1), rods (S2) and bars (S3), three different moisture content of tamarind fruits viz., 25% (M1), 23.5% (M2) and 22% (M3) on dry basis and three different rotational speed of the shaft viz., 1.1 m/s (N1), 1.3 m/s (N2) and 1.6m/s (N3) were considered for optimizing the selected parameters influencing deseeding efficiency. The influence of independent variables (sieves, moisture content and speed of the rotor shaft) on the dependent variable (deseeding efficiency) was analysed by a three factorial completely randomized block design using AGRES (AGRES stands for Agricultural Research) statistical package developed by Tamil Nadu Agricultural University, Coimbatore, India. Three replications were made to statistically evaluate the deseeding efficiency of the tamarind deseeder. The dependent and independent variables are given in the **Table 1**. Apart from independent variables, the clearance between studs and sieve and feed rate were kept constant at 8 mm and 60 kg/h, respectively.

Principle of working of the machine

Deseeder consisted of a rotor shaft encased with sieve. Studs were

Table 1 Number of levels and values of Independent and Dependent variables

Independent Variables	Symbol	Levels	Values	Dependent Variable
Moisture content, % (db)	M	3	25, 23.5, 22	Deseeding efficiency, %
Peripheral speed (m/s)	N	3	1.1, 1.3, 1.6	
Sieve	S	3	Made up of cylindrical rods, square bars and oblong hole sheet.	

No. of treatments = 3 × 3 × 3 = 27

Table 2 Analysis of variance for deseeding efficiency of deseeder for various speeds, moisture contents and sieves

Source	Degree of freedom	Sum of square	Mean sum square	F - ratio
Treatment	26	3,260.57	125.41	15.93**
Sieves (S)	2	2,727.82	1,363.91	173.25**
Moisture content (M)	2	0.04	0.02	0.002NS
Rotor shaft speed (N)	2	332.21	166.10	21.09**
SM	4	55.46	13.87	1.76NS
MN	4	25.95	6.49	0.08NS
SN	4	96.01	24.00	3.05*
SMN	8	23.07	2.88	0.37NS
Error	54	425.11	7.87	1.00
Total	80	3,685.68	46.07	5.85
SED		CD (0.05)		CD (0.01)
0.76		1.53		2.04

CV = 4.00%, *Significant at 5% level, ** Significant at 1% level

Table 3 Mean values of deseeding efficiency of tamarind deseeder

Treatments	N_1	N_2	N_3
$S_1 M_1$	75.23^b	81.77^a	77.70^b
$S_1 M_2$	73.77^b	82.73^a	77.63^b
$S_1 M_3$	76.33^b	80.73^a	77.66^b
$S_2 M_1$	66.20^d	$67.67^{c,d}$	69.00^c
$S_2 M_2$	65.47^d	$66.67^{c,d}$	67.10^c
$S_2 M_3$	66.67^d	$68.93^{c,d}$	71.00^c
$S_3 M_1$	61.00^e	$67.33^{c,d}$	65.50^d
$S_3 M_2$	61.80^e	$70.33^{c,d}$	65.60^d
$S_3 M_3$	60.40^e	$64.40^{c,d}$	65.43^d

^{a,b,c,d} and ^{e} = superscript with same letter indicates that treatments are on par welded over the rotor shaft in a zig-zag manner. When the rotor shaft is subjected to rotary motion, the studs on the rotor shaft exert impact load over the tamarind fruit which is being conveyed by the screw auger mounted on the same rotor shaft at the rear end. Thus, an impact load which is sufficient enough to create failure is exerted over the fruit. After the impact load, the tamarind is ready to leave its seed out of its pulp. Due to the simultaneous conveying and shearing action, the seeds are pushed through the sieve and the pulp segments are separated.

In this mechanism, two forces are acting over the fruit to deseed tamarind. Initially, impact load is exerted to create failure over the fruit and then, shearing force is exerted over the impacted fruit to separate seed out of pulp.

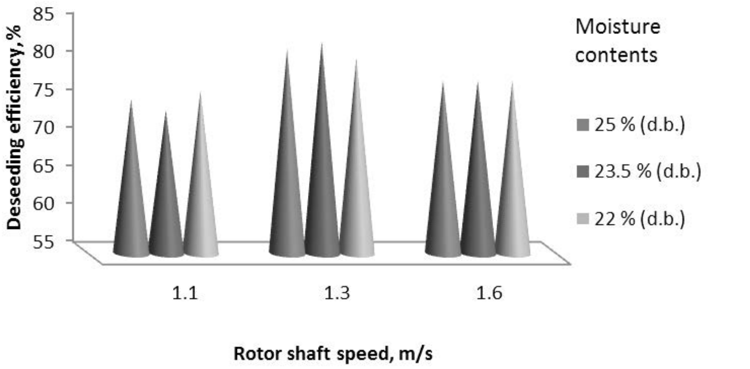


Fig. 5 Influence of moisture content, rotor shaft speed and oblong sieve on deseeding efficiency

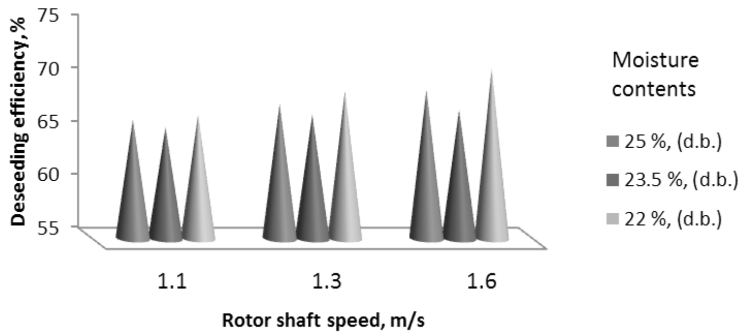


Fig. 6 Influence of moisture content, rotor shaft speed and sieve made up of rods on deseeding efficiency

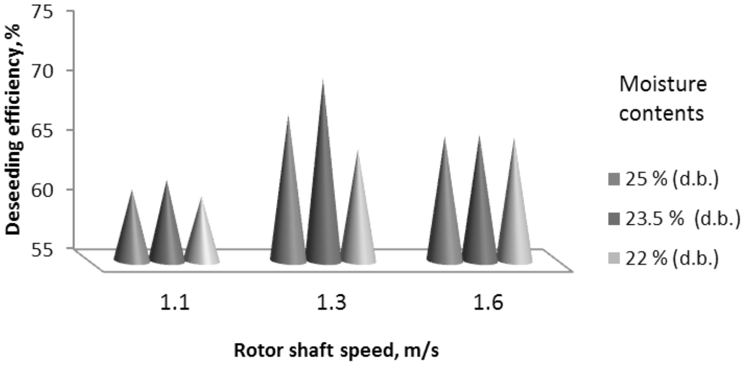


Fig. 7 Influence of moisture content, rotor shaft speed and sieve made up of bars on deseeding efficiency

Deseeding Efficiency

The procedure for determining the deseeding efficiency (per cent) of the newly developed machine was the same as that of finding the per cent seed loss (Parveen, 1999).

Deseeding efficiency = $S_1 / (S_1 + S_2)$

where,

S_1 = weight of seed that removed from the fruits, g.

S_2 = weight of seed collected from unseeded fruits, g.

Results and Discussion

Data were analysed and ANOVA obtained from the experimental design is given in the **Table 2**. While considering individual parameters, sieves and speed of the rotor shaft were influencing the deseeding efficiency of the tamarind seed remover. Selected three different sieves and three different speeds of the rotor shaft influenced the deseeding efficiency significantly at 1% level while considering the parameters individually. While considering the interactions, interaction of sieves with different speeds of the rotor shaft had significant influence on the deseeding efficiency of the tamarind deseeder at 5% level of significance. Hence, it was observed that among the three parameters, different sieves and rotational speeds of rotor shaft influenced the deseeding efficiency of the deseeder and deseeding efficiency was not influenced by the moisture contents of the tamarind considered for the test.

From the **Table 2**, it is noted that the deseeding efficiency of tamarind seed remover was not influenced by the moisture contents of tamarind which were considered for the evaluation. The moisture contents taken for the performance evaluation were insignificant in improving the performance of the deseeder. Because the difference between the moisture contents of tamarind was not deviating widely. Since the adjacent values of moisture content were taken, their effect on the deseeding efficiency would be insignificant. It was also observed that interaction of sieves with the moisture contents of tamarind and interaction of moisture contents with the speeds of the rotor shaft were insignificant. Interaction of sieves and moisture contents with the speeds of the rotor shaft was also found to be insignificant. It is observed from **Fig. 5** that deseeding efficiency increases with increase in peripheral speed of the rotor shaft and after attaining maximum at 1.3 m/s, it starts to decrease. This trend may be due to increasing rotor speed improves the conveyance of tamarind and hence residential period in the deseeding unit is reduced. The same trend is also observed in **Fig. 7** in contrast to that deseeding efficiency increases with increasing peripheral speed of rotor encased with sieve made up of rods as shown in the **Fig. 6**.

Based on the performance evaluation done by keeping rotor shaft speed and moisture content of tamarind as independent variables and deseeding efficiency as dependent variable, the treatment combination of perforated oblong sieve with the rotor shaft of 250 rpm to deseed the tamarind at the moisture content of 23.5% on dry basis was considered as the best among the twenty seven different treatments (**Table 3**) tested in AGRES package, since the maximum deseeding efficiency was obtained as 82%.

Conclusion

A machine operating on the principle of impact and simultaneous shearing force was developed and tested for its performance. Deseeding efficiency of the machine was found superior for the treatment combination of perforated oblong sieve with the rotor speed of 250 rpm (1.3 m/s) to deseed the tamarind at the moisture content of 23.5% on dry basis.

REFERENCES

Babu C. K., M. V. Ramkumar and B. Ranganna. 1999. Post harvest management of tamarind. All India Coordinated Research Program Manual. pp: 1-54.

Benero, J. R., A. J. Rodriguez and D. R. Collazo. 1972. Tamarind. Journal of the Agricultural University. Puerto Rico. 56 (2): 185-186.

Gunasena, H. P. M. and A. Hughes. 2000. Tamarind. Published by International Centre for Underutilized crops. University of Southampton. Southampton. UK, pp. 8

Mosqueda, M. 1980. Technology of clarified tamarind juice. In tropical and subtripicval fruits. AVI Publishing. Westport, pp. 375.

Parveen, K. B. 1999. Fabrication and performance evaluation of tomato seed extractor. Ph.D. thesis. Department of food and agricultural process engineering, Agricultural Engineering College and Research Institute, TNAU, Coimbatore.

Pustygin, M. A. 1948. Theory and technological calculation of threshing units. Moscow, Selkhoziz.

Rao, Y. S. and K. M. Mathew. 2001. Handbook of Herbs & Spices. Eds. K.V.Peter. Woodhead publishing limited. England. pp: 102

Salunkhe, D. K. and S. S. Kadam. 1995. Handbook of fruit science and technology: production, composition, storage and processing. CRC Press. pp. 578.

Shalini, R., D. Sharmila, E. Suganya and M. Thiyagu. 2007. Development and performance evaluation of tamarind pulp extractor. Unpublished UG project report. Department of Food and Agricultural Process Engineering. Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.

Spice Board of India. 2012. Web source from the official website of Spice Board of India. http://www.indianspices.com/html/s0420sts.htm

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Effect of Plant Crushing by Machine Traffic on Re-Generation of Multi-Cut Berseem Fodder

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Abstract

There are many soft stemmed multi-cut fodder crops (berseem, lucerne, stylo) grown in fodder production farms. Harvesting large areas of crop requires operation of heavy machinery in the field where crop is standing. A study was conducted to find out the crushing of plants by machinery and reduction in yield of crop in subsequent harvesting operation. Two types of harvesting machines viz. tractor operated cutter bar type fodder harvester and riding type engine operated fodder harvester were used for harvesting berseem during first three cuts of the crop. Plant crushing by the machinery was studied with number of plants falling in unit area of the path way of machinery. The growth pattern of plant crushed under tires was observed. In berseem field, one square meter area consisted of average 124.8 to 139.3 no. of plants during different cuts, out of which 34.03 to 52.0% plants were crushed by tyres in case of tractor operated harvester. Growth behaviour of crushed plants showed that there was tendency to heal the crushing of plant by tractor tyres. The visual demarcation between the crushed and not crushed plants reduced after four days. The trend of healing continued and after 12 days after operation, there was no difference between the plants that came under tyres and the plants that did not come under tyres. The yield of harvested crop was on par with manually harvested crop during 1st, 2nd and 3rd harvesting operation.

Key words: Harvesting, Mechanical, Fodder, Regeneration, Traffic

Introduction

Cultivated fodder crop harvesting in large fields requires operation of harvesting machinery in the standing crop. The quantity of work increases manifold in case of multi-cut fodder crop. Operation of machinery becomes mandatory in the fields for completion of harvesting in time. Multi-cut fodder crops like berseem, lucerne, stylo, oats are soft and succulent in nature and it was speculated that operation of heavy machinery in the field adversely affects regeneration of crop.

Bailey *et al.* (1996) studied soil stresses under a tractor tyre at various loads and inflation pressures and found that peak soil stresses and bulk density increased with increase in both dynamic load and inflation pressure. Increase in sol stresses suggests that with increase in speed of operation and inflation pressure of tyres, there is higher chance of damage to the soft fodder crops over which tractor runs with harvesting machinery.

Rodriguez *et al.* (2012) studied soil compaction under tyres for harvesting and transporting sugarcane at three inflation pressures (207, 276 and 345 kPa) and six loads ranging from 20 to 60 kN/tyre and found that contact surface between tyres and soil increased with increasing load and decreasing inflation pressure. However, contact pressure presented no defined pattern of variation. Among the different tyres tested (A-block shape tread; B-rib shape tread; C-low lug tread; D-high lug tread), tyre types A and B registered vertical stresses below 250 kPa at highest loads.

Nankali *et al.* (2012) analysed stress arising on tractor tyre soil interaction using symmetric Moony-Rivilin model having 2D finite element method and compared the same with measured field response data available in literature. The maximum soil-tyre pressure of 83.7 kPa was found for 70 kPa inflation pressure and 15 kN axel load which were approximately 30% less than the stress at the tyre contact patch in the field test as reported in the literature. Maximum vertical stress at contact area was 98.6 kPa for 150 kPa inflation pressure and 15 kN axel load.

Results of these studies state that there is considerable stress working on the soil-tyre interface while working in the field conditions. The stresses are further higher when tractor carried an implement for operation increasing the load of the tractor-implement system. When the soft stemmed fodder crop is harvested using tractor operated machinery in the field, the tractor tyres run on the remains of harvested plant. With the stress in the range of 83.7 kPa to 250 kPa arising out of the tyre soil interaction, there was a possibility of crushing of remains of the green succulent harvested plants. The concern of crop grower is that plants remain intact for maintaining the yield of fodder during next harvesting operation. With growing mechanization for harvesting of fodder crops, it becomes necessary to study the effect of stress on the regeneration of plant and yield of fodder crops on subsequent harvesting operation. So, in order to study the crushing of soft fodder crop with tractor tyres and heavy machinery, a study was taken up to find the effect of operation of machinery on the regeneration and yield of multi-cut fodder crop berseem in the central research farm of Indian Grassland and Fodder Research Institute, Jhansi, India.

Materials and Method

Fodder crop berseem was taken in this study since it is soft, succulent and provides multi-cut fodder crop. Two types of harvesting machines used for harvesting were Tractor operated cutter bar harvester and Engine operated riding type reaper.

Tractor operated cutter bar type fodder harvester mounted on three point linkage system harvested the crop and left it into the field without making windrows (**Fig. 1**). It was operated by a 26.1 kW capacity tractor that had tyres of size 315 × 711 mm and weight of 1,300 kg. Inflation pressure maintained in the rear tyres were 110 kPa and front tyres were 207 kPa. Inflation pressure of tyres was checked every time before harvesting of the crop. Fodder reaper had 1.8 m wide cutter bar that operated in the offset of tractor. For starting of harvesting in the field by tractor, headland of 2.0 m width was harvested manually to allow tractor movement without damaging of crop.

Fig. 1 Tractor operated cutter bar type fodder harvester

Fig. 2 Engine operated riding type fodder harvester

Engine operated riding type reaper also had a cutter bar of width 1.2 m for harvesting fodder crop. In this case harvested crop was left in a windrow (**Fig. 2**). This machine had two pneumatic tyres that were powered for motion and a third pneumatic, toed support wheel above which a seat was provided for operator. All the controls for operation of machine were near operator seat. Tyres of size 152 × 406 mm were used with this machine and it had weight of 400 kg. The inflation pressure in powered lugged wheels was maintained at 138 kPa and in the toed wheel it was maintained at 207 kPa. Inflation pressure was checked every time before operating the machine in the field.

The harvested crop in both the cases was collected and heaped on the side of field from where it was loaded in tractor trolley for transportation. In case of tractor operated fodder harvester, the crop from whole field needed raking and gathering, whereas engine operated riding type fodder harvester windrowed the crop and gathering was required from rows only. So, collection of harvested crop and heaping in the side of field in later case had less labour requirement for loading in to the trolley. Harvesting of crop was started five days after irrigation and was continued daily after that. After five days of irrigation, tyres do not sink in the field. Count of plant population was done in unit area. The area for plant population was taken on the path of run of tyres such that it covers the whole width of tyre while movement. Data was recorded up to three consecutive days from starting of harvesting operation. Total numbers of plants in unit area were counted by throwing 1 × 1 m square frame in the field after the tractor had run and tyres have made crushing print on the field. In this unit area, plants pressed by the tyres were counted. Plants having thickness more than 2 mm were considered for counting. Three replications of counting were done in each case. The soil sample was collected for measuring moisture content in the field.

Results and Discussion

Operation of tractor operated machinery and riding type harvester inserted pressure on the ground and on the plants of multi-cut fodder crop that was of multi-cut nature. The machines were operated in the field where crop was standing and crop production unit operations were being continued. So, the pressure applied by the tyres of running machinery on the plants and plant population coming under tyres were studied. After harvesting operation, the growth pattern of crop was studied.

Pressure Beneath Tyres

Maximum pressure beneath tyres was calculated for both tractor operated reaper and engine operated riding type reaper. In case of tractor operated machine, the mass supported by tyres were 1,300 kg of tractor, 300 kg of reaper and 100 kg of driver and fuel and others amounting to a total of 1,700 kg. It was considered that 80% of the weight falls on rear tyres of tractor and 75% of width of tyres was the length of tyre impression on the ground at any given instant. With these facts, maximum pressure beneath each traction tyre of tractor was found to be 89.6 kPa. Whereas, in case of riding type reaper total mass acting on the wheels was 350 kg including that of operator. Here also, it was considered that 80% weight falls on powered tyres and 75% of tyre width was the length of tyre impression on the ground at any given instant. With these figures, maximum pressure beneath each powered tyre of riding type reaper was 90 kPa.

Eventually, both the type of reapers viz. tractor operated and riding type applied near about the same maximum pressure of 89.6 and 90.0 kPa, respectively. So the magnitude of damage to the green plants while operation in the field may be considered to be of the same magnitude. In the harvesting and transportation studies of sugarcane, Rodriguez *et al.* (2012) found that maximum vertical stress occurring below tyre was 250 kPa for two types of tyres, which was much higher than the stress occurring below tyres (90.0 kPa) in case of berseem harvesting. The lower stress in case of fodder harvesting is due to use of light weight machinery compared to that used in sugar cane harvesting.

Plant Population

Average plant population before harvesting, plants crushed by the tyres, and erect plant population 12 days after harvesting was taken in the field conditions. **Table 1** shows average plant population in the field and plants coming under tyre of tractor operated cutter bar type fodder harvester.

Average of three counting of plant population showed that during 1st cut, plant population per unit area (1 m^2) varied from 120.0 to 144.0 out of which 24.4 to 27.0% plants got crushed by tractor tyres. Crushed plants laid down to earth in moist soil making a thorough impression of the path of run of tyres. Taking average of all the plants, there stood 130.9 plants per square meter out of which 25.9% plants came under tyres. Crushed plant were observed and photographed daily. The crushed plants on the path of tractor got up and stood erect and 12 days after operation the average plant population was 132.0. Plant population observed later was more because during collection of sample of erect population, the unit area where square frame was thrown for sampling was not exactly the same as taken before harvesting. In the broadcasted field of berseem there was high variation in number of plants per unit area from one place

Table 1 Average plant population, plants crushed with tyres and erect plant population 12 days after harvesting with tractor operated cutter bar type fodder harvester

Day	Plant population Number/m^2	No. of plants crushed	Per cent plant crushed Number /m^2	Erect plant population 12 days after harvesting Number/m^2	Moisture content of field, per cent (d.b.)
1st cut					
Day 1	120	29.3	24.4	127.3	18.4
Day 2	138	36.5	26.4	134.5	14.48
Day 3	134.7	36.3	27	134.3	12.83
Average	130.9	34.03	26	132	15.24
2nd cut					
Day 1	138.3	45	32.5	130	16.76
Day 2	105	35	33.3	133.3	15.31
Day 3	131	47.3	36.1	123	14.85
Average	124.8	42.43	34	128.8	15.64
3rd cut					
Day 1	139	52.7	37.7	142.3	17.88
Day 2	144	55	37.9	130	14.35
Day 3	135	48.3	35.8	142	12.33
Average	139.3	52	37.1	138.1	14.85

to another. During all the days of sample collection, erect plant population 12 days after harvesting was found to be independent of the plant population before harvesting. This stated that the plant that got crushed and fell to soil while operation of tractor tyres stood well and formed good crop canopy for another harvesting, as required in multi-cut fodder crops.

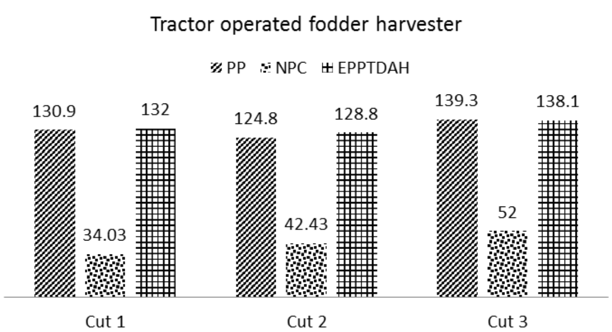
Similarly, in 2nd time harvesting operation, average plant population was 124.8 before harvesting and 34.0% plants came under tyres. Average plant population 12 days after harvesting was 128.8. Whereas, in the third time harvesting operation, average plant population was 139.3 before harvesting and 37.1% plants came under tyres. The average erect population 12 days after harvesting was found as 138.1. The plants crushed by the tyres of riding type fodder harvester are shown in **Table 2**.

In case of harvesting with riding type fodder harvester the same trend continued as with tractor operated fodder harvester. Average plant population in 1st, 2nd and 3rd cut varied from 121.4 to 129.3 before harvesting and 19.3 to 26.2% plants came under tyre. Whereas, plant population 12 days after harvesting was in the range of 133.2 to 138.0. Here also the plant population 12 days after operation was higher in some cases due to sampling place not being exactly the same as before operation and profuse growth of crop after harvesting. However, there was no definite relation of increase or decrease observed in plant population, before and after harvesting operation. This confirmed the results that crushed plants stood well forming good crop canopy for another harvest in case of second machine also i.e. engine operated riding type fodder harvester. The Average plant population, plant population that came under tyre and plant population 12 days after harvesting during 1st, 2nd and 3rd cut with tractor operated fodder harvester and riding type fodder harvester is shown in **Figs. 3** and **4**, respectively.

It was also observed from the data recorded that average plant population crushed by the tractor tyres increased slightly during subsequent operations. This was due to more growth of plants after harvesting operation. This may also be due to counting of plants thicker than 2

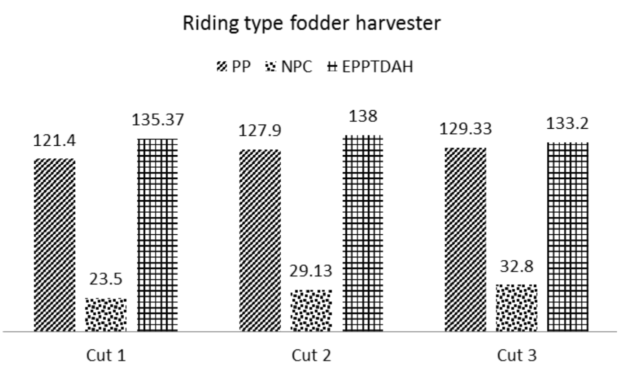
Table 2 Average plant population, plants crushed by tyres and erect plant population 12 days after harvesting with riding type fodder harvester

Operation	Plant population Number /m^2	No. of plants crushed	Per cent plant crushed Number/m^2	Erect plant population 12 days after harvesting Number/m^2	Moisture content of field, per cent (d.b.)
1st cut					
Day1	120	23.3	19.4	127.7	15.52
Day2	120.5	23.5	19.5	146.7	15.25
Day3	123.7	23.7	19.1	131.7	13.64
	121.4	23.5	19.3	135.4	14.8
2nd cut					
Day 1	136.3	27.7	20.3	149.3	15.67
Day 2	126.7	28.7	22.6	132	13.35
Day 3	120.7	31	25.7	132.7	12.11
	127.9	29.13	22.9	138	13.71
3rd cut					
Day 1	143	34	24.2	126.3	17.57
Day 2	111	32.7	30.6	136.3	15.3
Day 3	134	31.7	23.9	137	13.49
	129.3	32.8	26.2	133.2	15.45



PP: Plant population; NPC: Number of plants crushed; EPPTDAH: Erect plant population 12 days after harvesting

Fig. 3 Average plant population, number of plants crushed and erect plant population 12 days after harvesting during 1st, 2nd and 3rd cut with tractor operated harvester



PP: Plant population; NPC: Number of plants crushed; EPPTDAH: Erect plant population 12 days after harvesting

Fig. 4 Average plant population, number of plants crushed and erect plant population 12 days after harvesting during 1st, 2nd and 3rd cut with riding type reaper

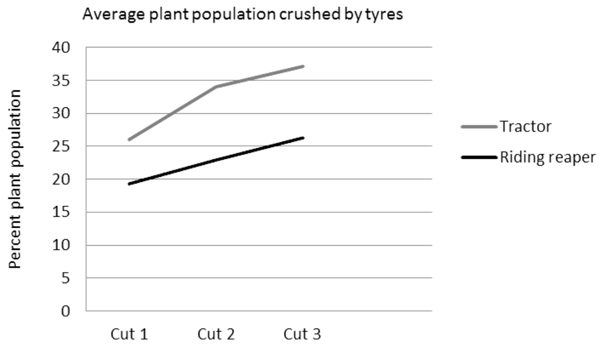


Fig. 5 Average plant population crushed by tyres during different cuts

Table 3 Average fodder yield during different number of cuts

No. of cut	Average fodder yield, q/ha		
	Tractor operated harvester	Riding type reaper	Manual harvesting with sickle
1st	97	101.7	101.7
2nd	210	210	223.3
3rd	226.7	223.3	223.3

mm only that might have grown in subsequent operations. **Fig. 5** shows average plant population crushed by tyres during different cuts.

Growth Behaviour

The growth pattern of the plants crushed by tyres was photographed daily after harvesting operation. It was observed that there was a tendency of healing of the plants crushed by tyres. It was also observed that four days after harvesting, the plants that came under tyre also started growing in the same pattern like other plants. Eight days after harvesting, it was difficult to differentiate between the plants that came under tyres and twelve days after harvesting, there was absolutely no difference among the plants that came under tyres and that did not come under tyres. This resulted in the yield of the crushed plants being equivalent to that of the non-crushed plants. **Table 3** shows average fodder yield from the fields harvested using tractor operated fodder harvester, riding type fodder harvester and manual sickle.

Table 3 shows that yield of fodder was not significantly different when it was harvested manually or using any of the machines taken in this study. This was the trend during all the three i.e. 1st, 2nd and 3rd number of harvesting. So, operation of fodder harvesting machinery can be done without sacrificing the yield due to mechanical crushing.

Conclusions

It was concluded that operation of tractor operated machinery and riding type reapers do not affect the growth of multi-cut soft fodder crop. The plant population that is crushed under tyres grows equally well and stands erect fully 12 days after harvesting. The growth behaviour of crushed and not crushed plants remains the same and the yield has no significant difference up to three number of harvesting operation.

Acknowledgement

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REFERENCES

Bailey, A. C., R. L. Raper, T. R. Way, E. C. Burt and C. E. Johnson. 1996. Soil stresses under a tractor tyre at various loads and inflation pressures. Journal of Terramechanics. Vol 33 (1), 1-11.

Khar, S. and S. S. Ahuja. 2007. Performance evaluation of self-propelled flail type forage harvester for fodder maize. Journal of research, SKUAST-J, Vol. 6 (1) Online ISSN : 0972-7469.

Rodriguez Luis, A., J. Valencia John and A. Urbano Jaime. 2012. Soil compaction and tyres for harvesting and transporting sugarcane. Journal of Terramechanics. Vol 49 (3-4), 183-189.

Nankali, N., M. Namjoo and M. R. Maleki. 2012. Stress analysis of tractor tire interacting with soil using 2D finite element method. International Journal of advanced design and manufacturing technology. Vol 5 (3), 107-111.

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Design, Fabrication and Drying Performance of Flash Dryer for High Quality Cassava Flour

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Abstract

The design and fabrication of processing equipment in most developing countries are still faced with a number of problems due to lack of appropriate tools and equipment. In all the cases the resulting equipment are noisy, ineffective and with neither good finishing nor appearance. This study presents the use of software in appropriate design, drawing and fabrication of machine component parts for a flash dryer for high quality cassava flour. Drawings and 3D model of the components, sub-assemblies and complete machine assembly were produced using Computer Aided Design (CAD) and profile development software. The flash dryer was fabricated and installed at a Farm in Nigeria and tested under industrial conditions. The results showed that its fuel consumption was 13 L/h and the moisture content of the product was in the range of 5-7% from initial moisture content of 40-45% db. and for a feed rate of 702 kg/h of cassava mash. The computational results are in agreement with the experimental data. These values are much lower than the corresponding values obtained from two existing flash dryers in the farm when the same cassava mash was used. The quality of the cassava flour produced from the new flash dryer falls within the acceptable Nigerian standards for this product.

Introduction

Cassava is a major food crop particularly in the developing countries of the sub-Saharan Africa and the Carribean (Hahn *et al*., 1989; Onabolu *et al*., 1998). It is the third most important staple food in the tropics after rice and maize. It provides 37, 12 and 7% of the calorie requirement in Africa, Latin America and Asia respectively (Kajuna *et al*., 2001, Oyewole and Asagbra, 2003). Apart from being a food crop, it is also gradually gaining a strategic position in the world trade as a result of the effort of various governments and private sector in developing novel, value added cassava-based products for human consumption and industrial uses. Thus a lot of studies have been carried out on its mechanization and processing (Hahn and Keyer, 1985; Raji and Igbeka, 1994; Nweke *et al*., 2002; Ahemen and Raji, 2008, Raji *et al*., 2008). Local (mainstream) manufacturers have come up with diverse forms of innovation and improvements to enable processors to overcome some of their limitations. The locally adapted post-harvest technologies were introduced by the IITA-implemented Cassava Enterprise Development Project (CEDP) in support of the PIC (Sanni *et al*., 2005, 2006a, 2007). These machineries include mobile graters, flash dryers, pulverizers, centrifuges and plate mills. Other low cost innovations suitable for micro-processing included: the improvement of the cassava wet mash dewatering equipment from screws to hydraulic mechanism; the design of a mobile grater; improvement in cassava sieves; the development of a low cost cassava dryer that can use charcoals and kerosene (for drying of cassava chips and pellets); the integration of the cassava grater, cassava press, cassava sieve and gari fryer in a single package.

One of cassava products with strong potentials for industrial use in Nigeria is cassava flour. Drying cassava mash produces it. A number of dryers, including sun drying, are used to dry cassava mash (Sanni, 2011). However, a flash dryer appears to be the most economical choice for drying mash and solids that have low moisture content and most especially heat sensitive materials. A single operation combines the necessary mixing, heat and mass transfer for drying a solid. They are useful for moist, powdery, granular and crystallized materials, including wet solids discharged from centrifuges, rotary filters and filter presses (Heβ, 1984; Kudra *et al*., 1989). As the name implies, drying occurs "in a flash". This flash mode results in a very short resident time of particles, minimal contact with the dryer surfaces and proper mixing with clean uncontaminated drying air (Blasco and Alvarez, 1999; Korn, 2001). This ensures very clean and hygienic cassava flour with low moisture content. As a result of these advantages, many flash dryers are fabricated and used in Nigeria for drying cassava mash to obtain flour.

Most of the flash dryers fabricated locally in Nigeria are inefficient in terms of energy usage and the consistency in the quality of the cassava flour cannot be guaranteed (Balami *et al*., 2012). These dryers, though effective, are inefficient in terms of energy usage and the consistency in the quality of the cassava flour cannot be guaranteed. In Nigeria, most of the fabricators involved in the production of these machines are craftsmen or engineering technicians with some fabrication experiences. Apart from this, some of the basic tools and other infrastructure that are necessary for producing these components with high precision are either not available or inadequate. To address these issues, a flash dryer with many special shapes, profiles and transitions has been designed, fabricated and tested (Kuye *et al*., 2011) for the production of 500 kg/h of cassava flour. In this study we demonstrated how some of the special components of the designed flash dryer were fabricated in a workshop that lacks basic sheet metal machine tools required for this fabrication. The performance of this new flash dryer was evaluated.

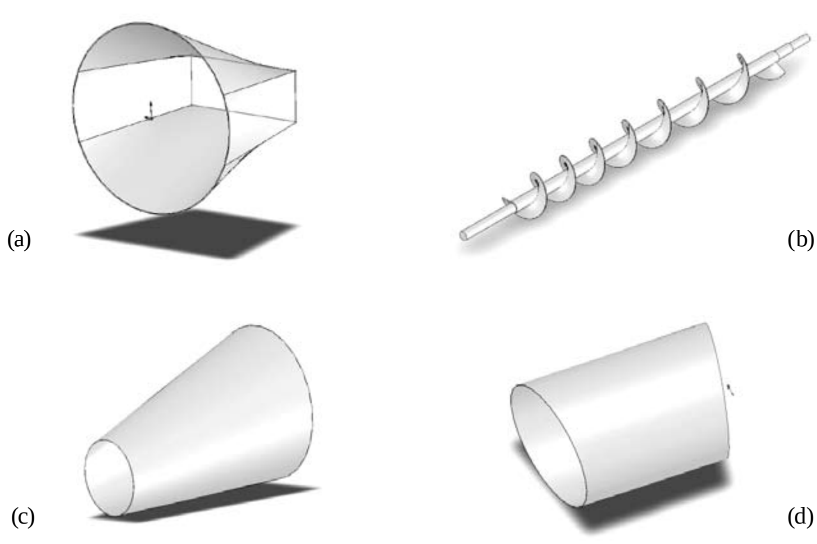

Fig. 1 Special shapes (a) circle to rectangle transition, (b) variable pitch auger, (c) oblique cone and (d) segmented bend.

Materials and Methods

Design and Fabrication

The following equipment and tools were used for the fabrication: (a) Lathe, locally fabricated sheet rolling, Stick Welding and hand powered tools

(b) Computer Systems, accessories and stationeries

(c) Two softwares namely: Evaluation version of Plate 'n' Sheet and AutoCAD 2007.

The special components encountered which were difficult to fabricate included segmented bends, shape transitions, variable pitch auger, oblique and straight cones (see **Fig. 1**). The general steps used to make these components are:

1) Start the Plate 'n' Sheet software. Select the special shape template and generate its development.
2) Import the development from Plate 'n' Sheet into AutoCAD. Use the AutoCAD scaling capability to restore the original size of the development. This second step was necessary because we did not have the full version of Plate 'n' Sheet.
3) Print different segments of the development from AutoCAD on A4 papers. Join the papers and then cut out the actual development.
4) Transfer actual development to metal
5) Roll, bend and/or cut as appropriate to form the desired shape of the component.
6) Weld appropriately.

The details of the new flash dryer design can be obtained in Kuye *et al*. (2011). The dryer system was conceptualized for the production of industrial grade cassava flour or starch from grated and dewatered cassava mash, starch cake and fufu cake. The block diagram for the new flash dryer is presented in **Fig. 2**. The feeding system was designed to deliver 820 kg/hr of dewatered cassava mash to the drying column. A rotary airlock was incorporated at the entrance to the drying duct to prevent escape of hot air through the feeding system that can result in the backflow of pulverized materials, because it is a positive pressure dryer. The feeding mechanism delivers the particles into the throat of a venturi incorporated before the drying duct. The dryer was designed to produce flour at 10% moisture content which is below the 13% maximum moisture content recommended for dry cassava products (Sanni *et al*., 2005). This gives allowance for the possible rise in moisture content during storage. The dried product is separated from the air stream in a cyclone. The flash dryer has an integrated Motor Control Centre (MCC) incorporated with various electrical/electronic devices that enabled temperature and product moisture control automatically.

Dryer Evaluation

The following tests were carried out; each test was carried out in triplicate:

a) Fuel consumption rate: This was measured by measuring the fuel level in the fuel tank at regular intervals of time.

b) The feed rate: The variation of the feed rate with the speed of motor attached to the feeding mechanism was measured. The feed rate was calculated by weighing the amount of cake fed to the dryer during a given time.

c) Temperature profile: The temperature variation was monitored at the venturi inlet every morning at cold start for a week. At the close of operation each day the cooling of the dryer was also monitored.

d) Moisture content: This was measured to ensure that the quantity obtained represented the expected and that the materials were not retained and accumulating in the dryer. Moisture content was obtained by the use of moisture meter and oven method (ASAE 1983)

e) Proximate analysis and product colour: Samples of the products were collected and analysed for proximate composition, particle size distribution was determined for the material, using a sieving method (Ro-Tap, with tapping, 5 minutes total time); and colour using method described by AOAC (1995). The Hunter's L*a*b colour analysis of the samples were carried out and compared with the results of a white paper to show the level of lightness of the flour as described by Shittu *et al.* (2007).

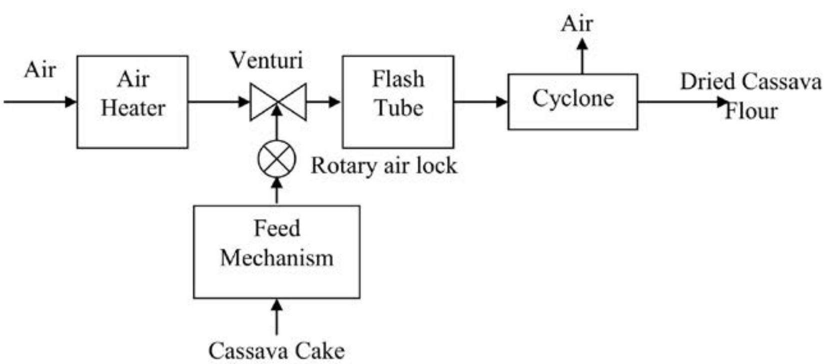

Fig. 2 Block diagram of the Flash Dryer System

Results and Discussion

Fabrication Effectiveness and Precision

The results obtained when the methodology presented in the previous section was used to produce circular to rectangular transition are shown in **Figs. 3-6**. This transition occurs at the entrance of the cyclone. The Plate 'n' Sheet template for this transition is shown in **Fig. 3**. It is at this stage that the dimensions are specified. The dimensions were obtained from the design specifications. The corresponding development is shown in **Fig. 4**. Notice that the bend lines were used to ensure that the exact software calculated bend angles were maintained to get smooth finishing during the bending/rolling.

The image generated when the Plate'n'Sheet development was imported into AutoCAD is shown in **Fig. 5**. The size of the component to be produced requires a template of a substantial size and there is simply no printer large enough to generate the template to that size. The aspect ratio of the development generated with Plate'n'Sheet was used to advantage. To produce an actual size of the template, the redrawn template was set on grids and selective printing of parts of the template was made to a printing scale of 1:1 before it was then assembled.

The development of the actual part was cut out from the assembled printout and transferred to metal (see **Fig. 6**). The printout was made on paper and reinforced to reduce error during the transfer to metal.

The actual assembled section is shown in **Fig. 7**.

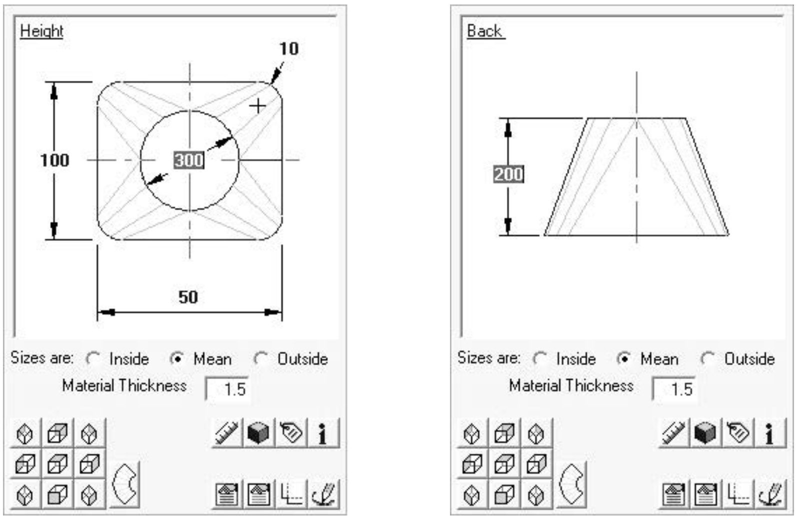

Fig. 3 Plate 'n' Sheet template for circle to rectangle transition

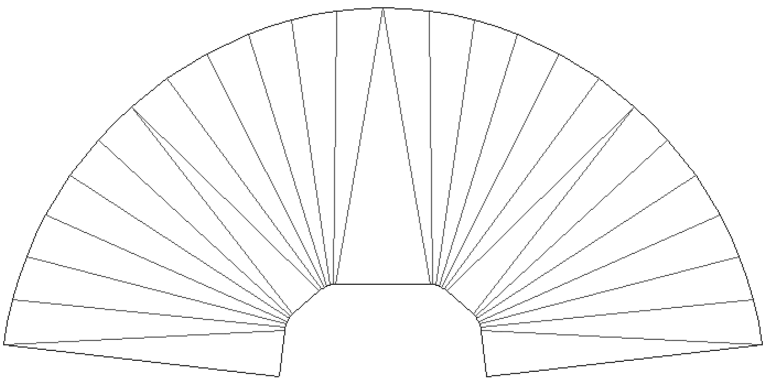

Fig. 4 Screenshot of the output from Plate'n'Sheet

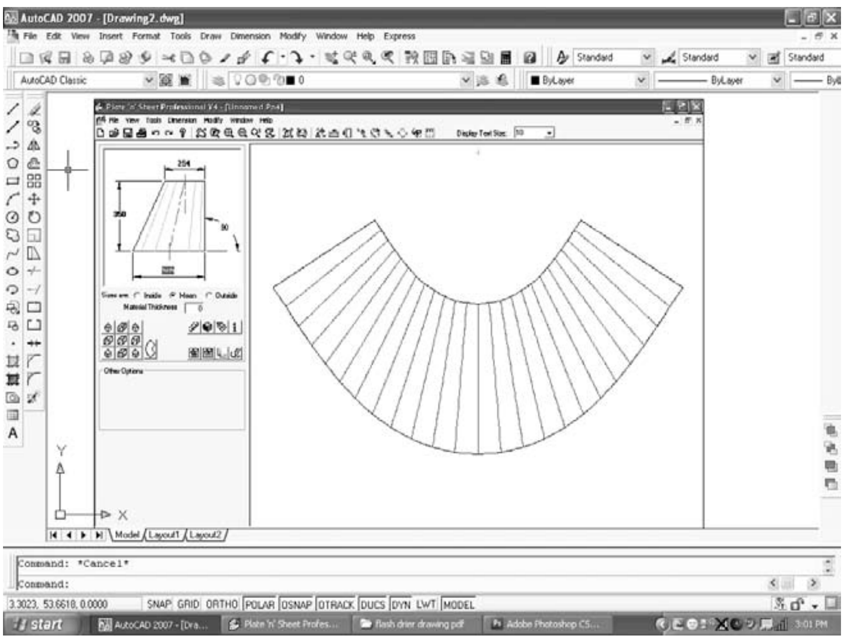

Fig. 5 Screenshot of Plate'n'sheet template inside AutoCAD

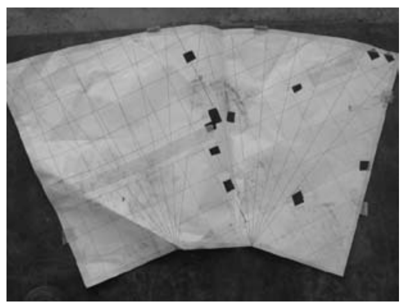

Fig. 6 Assembled paper template of the development

Fig. 7 Actual circular to rectangular section

Similar approach was used to produce and assemble the other special sections. Some of these are shown in **Figs. 8-10**. Clearly, the use of these software in aiding the development and design of the components resulted in components fabricated and produced with precision. The assembled machine, which weighs more than 20 tonnes was done on site away from the workshop where the fabrication was done. The component parts fitted well on site. This eliminated the need to either carry heavy machine over a long distance for installation or transfer of tools and equipment needed for fabrication to the site where the machine is to be installed. High precision and fit were observed in the joints and the components were neatly finished. These resulted in a heavy machine with very minimal vibration and very low noise level compared to the other existing machines.

Fig. 8 Some special sections of the flash dryer

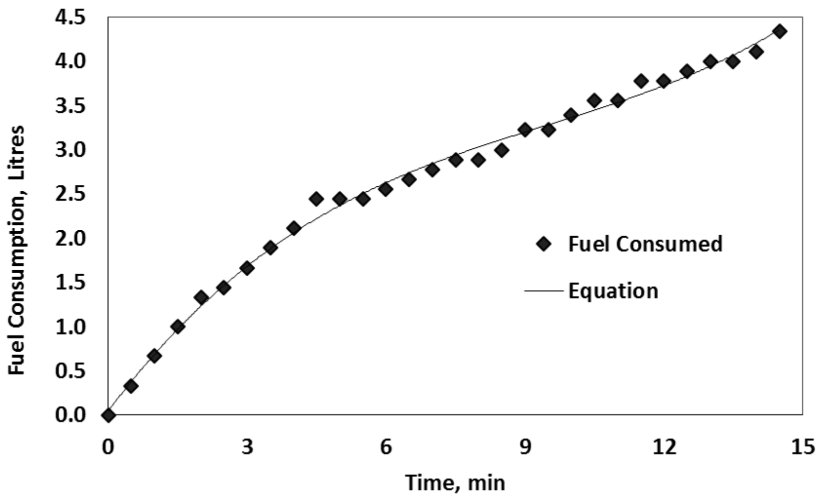

Fig. 9 Fuel Consumption

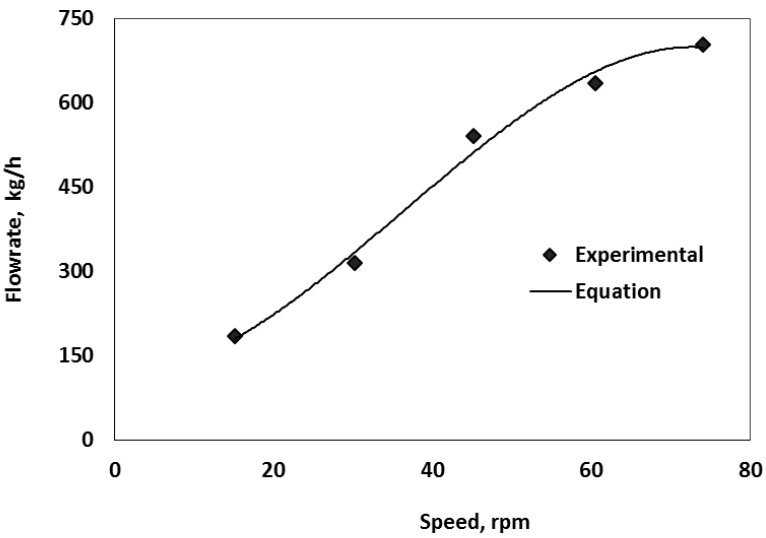

Fig. 10 Wet mash feeding rate with speed

Fuel Consumption

The result of the fuel consumption rate obtained during the tests is shown in **Fig. 9** for the first 15 minutes of operation. Further readings also showed that an average of 13 L/h of fuel was consumed by the new flash dryer during operation. The functional relationship of the fuel consumption (FC, litres) obtained by regression analysis of the data taken with time (t, mins) is given as

$$FC = 0.0020t^3 - 0.0565t^2 + 0.6976t + 0.0463 \qquad (1)$$

The correlation coefficient is close to 1 ($R^2 = 0.9952$). This means that Equation (1) is almost a perfect fit for the experimental data. Hence, Equation 1 can be used to predict fuel consumption and consumption rate within range shown in **Fig. 9**.

Feed Rate

The flash dryer was designed for a feed rate of 820 kg/h and a motor speed of 72 rpm. However, **Fig. 10** indicates that the maximum feed rate observed was 702 kg/h at a motor speed of 72 rpm. **Fig. 10** can be represented by equation 2 using regression analysis. The correlation coefficient is $R^2 = 0.9907$

$$FR = -0.003s^3 + 0.3279s^2 + 0.1311s + 113.81 \qquad (2)$$

Where, FR is flow rate (kg/h)and s speed (rpm)

Temperature Profile

As stated earlier, the flash dryer

has an integrated MCC. The set point for the temperature was fixed at 120°C. This was to ensure that the cassava mash can be dried (within its short residence time and) without thermal degradation of the product. The dryer achieved the preset temperature of 120°C in 5 minutes from cold start.

The temperature readings at the venturi throat just before the hot air mixes with the pulverized products is presented in **Fig. 11**. This was monitored for a week every morning during cold starting. The burner is automatically turned off by MCC when the temperature is within the preset temperature ±5°C. This explained the fluctuation of temperatures between 117°C and 123°C in response to the auto shutting and starting of the burner (**Fig. 11**). This is also an indication that the MCC is capable of maintaining the set point.

After drying, the dryer cooling was also monitored and the cooling curve is presented in **Fig. 11**. It took about 18 minutes to cool to below about 40°C. This slow cooling rate is advantageous as it helps in fuel conservation when the dryer is to be operated within this period of shutting down. This helps in determining the period during which cold starting is necessary. The cooling shows that cold starting is after about 20 minutes of shutting down. It will take less time to heat up to the preset temperature from hot start, that is, if the dryer is started before it fully cooled down. Further retention of cooling could be achieved by lagging of the flash tube with fibre glass insulating material.

Moisture Content

The moisture content of the cassava mash was 45% while that of the cassava flour obtained from flash dryer ranged from 5%-7%. This value is much lower than the standard specification (13%) for cassava flour (Sanni *et al.*, 2005). It is also pertinent to note that the moisture content of the flour produced by the other two existing flash dryers was on average 9.41% for the same cassava mash input (see **Table 1**). In a study on a mini flash dryer with a feed rate of 125.6 g of cassava mash, Ajao and Adegun (2009) reported a moisture content of 13.9% after the first pass for their cassava flour. This probably explained why Ajao and Adegun (2009) had to use three passes to reduce the moisture content further. The lower the initial moisture content of a product to be stored the better the storage stability of the product. Also the lower the initial moisture content of the product the higher the efficiency of the drying method because this shows that much of the water contained in the fresh sample or product had been removed (Pierre, 1989).

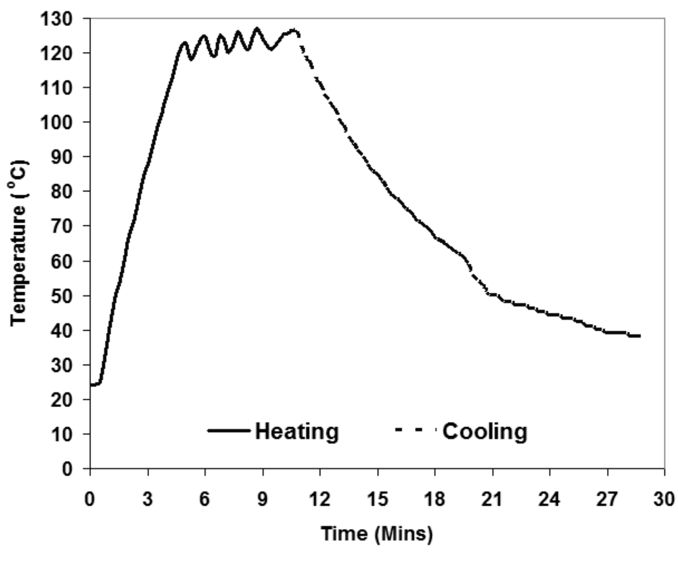

Fig. 11 Temperature profile during heating and cooling of the dryer at the venturi throat

Table 1 Average Proximate analysis of the flash dried cassava flour samples

High Quality Cassava Flour	MC (%)	Ash (%)	Protein (%)	Final Viscosity	Pasting Temp.
Sample dried in existing dryers	9.41	1.32	0.34	240.5	75.25
Sample dried in the new dryer	5.67	1.41	0.52	127.33	76.9
Recommended standard value	9-13	0.1 (max)	1 (min)	-	-

Min-minimum. Max-maximum

Proximate Analysis

The proximate analysis (ash, protein, viscosity and pasting temperature) of the cassava flour obtained from the new flash dryer are presented in **Table 1**. Also shown in **Table 1** is the proximate analysis of the cassava from an existing flash dryer using the same cassava mash used for the new flash dryer. The results indicate that the moisture content achieved is much lower than the maximum recommended standard and those obtained from existing flash dryers. However, the protein and the ash content do not compare favourably well with the recommended standard values. This may be because these parameters are also dependent on other parameters (such as chemical composition) apart from the drying technique used. The final viscosity and pasting temperature compared better with the product from the existing dryers. Final viscosity is the most commonly used parameter to determine a particular starch-based sample's quality as it indicates the ability of the material to form gel after cooking (Sanni *et al*., 2006b).

Colour

The results of the Hunter's L*a*b colour analysis of the samples compared with the results of a white paper to show the level of lightness of the flour are shown in **Table 2**. In all the brightness values of the samples and the white paper are on the positive side of the standard. The values compared with the white paper also show that the lightness of the flour is comparable with white paper. The other significant values are the b value which indicates the yellowness of the sample being on the positive yellow. This adds to the brightness as the b value for the white paper is an indication of blue component. The results also indicate that the new dryer produces flour that are brighter in colour compared to the existing ones.

Conclusions

A new flash dryer has been designed, fabricated, installed and tested under industrial conditions. The results obtained showed that the quality of the cassava flour produced by the new dryer is quite high and within the limits set by the relevant Nigerian standards. The moisture content was in the range 5-7% while the fuel consumption was 13 L/h. The quality of the cassava flour produced was also much better than those from existing flash dryers when fed with the same cassava mash.

Table 2 Colour Analysis of the flash dried cassava flour samples

	L	a	b	ΔE
White Paper (Control)	87.48	2.83	-0.84	-207.957
Samples dried in existing dryers	91.97	-0.42	16.69	-644.691
Samples dried in the new dryer	90.29	0.13	17.95	210.6917

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REFERENCES

AOAC. 1995. Official Methods of Analysis.16th Edition. Association of Official Analytical Chemists. Arlington, USA.

Ahemen, S. and A. O. Raji. 2008. Development and performance evaluation of a motorized rasping machine for Tacca involucrata starch production. Journal of Agricultural Engineering and Technology, 16 (1): 52-63. www.niae.net (Nigeria).

Ajao, K. R. and I. K. Adegun. 2009. Performance evaluation of a locally fabricated mini cassava flash dryer. Journal of Agricultural Technology, 5 (2): 281-289.

ASAE. 1983. Moisture Measurement - Grains and seeds, ASAE Standard S352.1. American Society of Agricultural Engineers, USA, St. Joseph, Michigan.

Blasco, R. and P. I. Alvarez. 1999. Flash drying of fish meals with superheated steam: Isothermal process. Drying technology, 7 (4-5): 775-790.

Hahn, S. K. and J. Keyer. 1985. Cassava: A basic food for Africa. Outlook Agriculture, 14 (9): 5-9.

Hahn, S. K., J. C. G. Isoba and T. Ikotun. 1989. Resistance breeding in root and tuber crops at International Institute of Tropical Agriculture. Crop Protection, 8 (3): 147-168.

Heβ, D. 1984. Comparison of processing economics of different starch dryers. Starch/Stärke 36: 369-373.

Kajuna, S. T. A. R., V. C. K. Silayo, A. Mkenola and P. J. J. Makungu. 2001. Thin-layer drying of diced cassava roots. African Journal Science and Technology, 2 (2): 94-100.

Korn, O. 2001. Cyclone dryer: a pneumatic dryer with increased solid residence time. Drying Technology, 19 (8): 1925-1937.

Kudra, T., E. Pallai, Z. Bartczaki and M. Peter. 1989. Drying of paste-like materials in screw-type spouted-bed and spin-flash dryers. Drying Technology 7 (3): 583-597.

Kuye, A., D. B. Ayo, L. O. Sanni, A. O. Raji, E. I. Kwaya, O. O. Otuu, W. B. Asiru, B. Alenkhe, I. B. Abdulkareem, B. Bamkefa, G. Tarawali and A. G. O. Dixon. 2011. Design and Fabrication of a Flash Dryer for the Production of High Quality Cassava Flour. International Institute of Tropical Agriculture, Ibadan, Nigeria, 50 pp.

Nweke, F. I., D. S. C. Spencer and J. K. Lynam. 2002. The Cassava transformation: Africans best kept secret. Michigan State University Press, East Lansing, Michigan, USA. 273 pp.

Onabolu, A., A. A. Abass and Bokanga M. 1998. New food products from cassava. Ibadan: International Institute of Tropical Agriculture, Ibadan. Nigeria. 40 pp.

Oyewole, O. B. and Y. Asagbra. 2003. Improving traditional cassava processing for nutritional enhancement In. International work-

shop on Food based approaches for a healthy nutrition Ouagadougou, November 2003, pp: 23-28
Pierre, S. 1989. Cassava. Macmillan Education Ltd. London, Technical Centre for Agriculture and Rural Cooperation, Wageningen, the Netherlands, pp. 1-2, 30-31, 76.
Raji, A. O. and J. C. Igbeka. 1994. A pedal operated chipping and slicing machine for tubers. Journal of Agricultural Engineering and Technology. Vol. 2: 90-94.
Raji, A. O., N. Kanwanya, L. O. Sanni, W. B. Asiru, A. Dixon and P. Ilona. 2008. Optimisation of cassava pellet processing method. International Journal of Food Engineering, Vol. 4, Issue 2, Article 5, pages 1-15.
Sanni, L. O., B. Maziya-Dixon, J. Akanya, C. I. Okoro, Y. Alaya, C. V. Egwuonwu, R. Okechukwu, C. Ezedinma, M. Akoroda, J. Lemchi, E. Okoro and A. Dixon. 2005. Standards for cassava products and guidelines for export. Ibadan, Nigeria. IITA.
Sanni, L. O., C. Ezedinma, R. U. Okechukwu, M. Patino, M. O. Akoroda, B. Maziya, J. Dixon, P. Lemchi, E. Ilona, G. Okoro, T. Tarawali, B. Awodeyi, N. Bamkefa, F. Ogbe Nnaji and A. G. O. Dixon. 2006a. Catalogue of postharvest equipment for cassava processing. International Institute of Tropical Agriculture, Ibadan, Nigeria. ISBN 978 131 271 8, 132 pp.
Sanni, L. O., A. A. Adebowale, T. A. Filani, O. B. Oyewole and A. Westby. 2006b. Quality of flash and rotary dried fufu flour. Journal of Food, Agriculture and Environment, 4 (3 and 4): 74-78.
Sanni, L. O., Alenkhe, B., Edosio, R., Patino, M. and Dixon, A (2007). Technology transfer in developing countries: Capitalizing on equipment development. In Journal of Food, Agriculture and Environment, 5 (2): 88-91.
Sanni, L. O. 2011. Process and product innovations in the cassava agro-industrial sectors in Africa: The stimulating effect of presidential initiatives. In: da Silva, C.A. and Mhlanga, N. (Eds.). Innovative Policies and Institutions to Support Agro-Industries Development. Rome, Italy. Food and Agriculture Organization of the United Nations. pp. 283-304.
Shittu, T. A., A. O. Raji and L. O. Sanni. 2007. Bread from composite cassava wheat flour: I. Effect of baking time and temperature on some physical properties of bread loaf. Food Research International 40: 280-290.

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Effect of Planting of Onion Sets in Different Orientations on Crop Growth for Development of Onion Set Planter

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Abstract

The planting system for aggregatum group onion is by planting sets (bulblets). The sets are planted vertically with the basal root plate down and pressed below the moist soil surface upto the neck portion and the top portion exposed above the soil. While sown by a planter, the sets are dropped from a height. Hence experiments were conducted to study

i) depositing orientation of onion sets when dropped from different heights of 200, 300, 400, 500 and 600 mm
ii) effect of four different planting orientations (root portion down, root portion up, horizontal and inclined orientation) on growth parameters of onion crop and
iii) orientation of onion set in metering mechanism before metering.

It was observed that about 80 per cent of the onion sets were deposited on the soil in horizontal orientation irrespective of the height of drop and initial orientation. It was observed that the onion sets planted root side down and in horizontal and inclined orientation resulted in 100% germination and maximum number of shoots. It was also observed that about 18% of the onion sets had root portion up orientation at delivery point of a inclined plate metering unit and about 2.25% onion sets had root portion up orientation at deposition on soil. The yield loss due to onion sets deposited as root portion up was negligible. Therefore, it was concluded that a onion set planter planting onion sets irrespective of the orientation will not affect the yield of onion crop.

Keywords: Onion sets, Aggregatum type onion, Planting orientation, planter, Inclined plate metering mechanism, Germination

Introduction

Onion (*Allium cepa* L.) is one of the most important crops widely used in world and has a very high potential for export. India has the second largest area of about 1.064 million ha (19.9%) under onion cultivation with production of about 15.118 million tonne (13%). Aggregatum group onions also called as multiplier onions are mainly grown in Tamil Nadu state due to the food habits in Tamil Nadu and also to have an early crop. Area under onion cultivation in Tamil Nadu is increasing every year as 33,800 ha during 2010-11 to 37,120 ha during 2011-2012 to 37,700 ha during 2012-2013. When compared to any other vegetable crops, onion is planted with very close spacing. Due to this, the labour requirement for planting is high, also labourers demand higher wages for onion planting. This

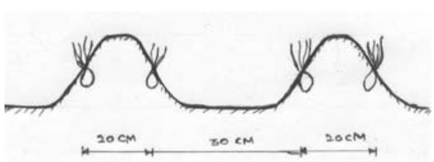


Fig. 1 Planting system of onion sets

leads to higher cost of cultivation. Hence, development of a suitable planter for planting onion sets will reduce the planting cost of onion.

Generally three systems of planting are employed viz., direct seeding, transplanting and planting onion sets (small dry bulbs/bulblets). The planting material for aggregatum group onion is onion sets. Onions stored for a period of 8-10 weeks are used as planting material. The group of onion is split into single onion sets and single onion sets are used.

During the manual planting of onion set the field is prepared by ploughing and ridges are made at a distance of 300-450 mm. The field is irrigated and the onion sets are planted vertically with the root portion down. The top portion of the onion set is exposed above the soil. Spacing between the sets in rows is about 100 mm (**Fig. 1**). In a planter, generally the planting material (onion sets) are dropped by a metering mechanism from a height into the furrows. Garlic cloves are also planted in the similar way of onion sets planting. Orlowski and Rekowska (1992) conducted a three year experiment to investigate the effects of different clove sowing methods on garlic yield. Their treatments were (1) bud pointed upward (conventional), (2) bud pointed downward, (3) bud pointed either side; and (4) bud at any random position (similar to machine sowing). The dependent variables measured were the number of plants emerged, plant height, garlic yield and quality. The results showed that the treatments 1 and 2 had the highest and lowest yield, respectively, the treatments 3 and 4 didn't show any significant difference in yield, and the treatment 4 had about 13.7-19.4% lower production cost than that of treatment 1 with no significant difference in quality. Jiraporn *et al.* (2010) conducted experiments to optimize the height of seed delivery tube above ground level for 10-row tractor operated garlic planter and observed that height of the seed delivery tube at 300 mm above ground level provided the lowest variation of 25 mm, from the line of motion at a forward speed 1.67 km/h.

The onion sets will be dropped in any one of the four root portion orientations viz., a) down, b) up, c) horizontal and d) inclined (**Fig. 2**). Hence experiments were conducted

i) to find out the depositing orientation of onion sets while dropped from different heights and at different orientations at initial position,

ii) to study the effect of four different planting orientations on growth parameters of onion crop and

iii) to study the orientation of onion sets in metering mechanism at delivery point and its effect on germination.

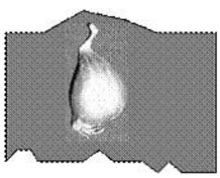
Materials and Methods

Depositing Orientation of Onion Sets

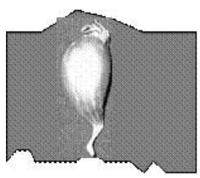
Experiment was conducted to find out the orientation of onion sets while dropped from different heights and at different orientations at initial position (at rest). Wet clay was used to collect the dropped onion sets as the orientation could be maintained by the clay when the onion set would touch the ground (**Fig. 3**). Onion sets were dropped one by one from five different heights viz., 200 mm, 300 mm, 400 mm, 500 mm and 600 mm. At each height the onion sets were maintained at three orientations viz., root portion down, root portion up and horizontal position. The dropped onion sets were collected in a tray filled with clay and the orientation of deposited onion sets were observed.

Growth Parameters of Onion Sets While Planting at Different Orientations

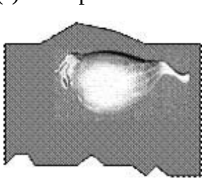
During manual planting as the root portion of the onion set is pressed down to the moist soil, the germination percentage will be 100% (assuming 100% viability of onion sets). However, when the onion sets are dropped by a planting mechanism, the sets would be planted in any one of the following four root portion orientations a) down, b) up, c) horizontal and d) inclined. A pot culture experiment was conducted to study the effect of different orientation of planting on plant



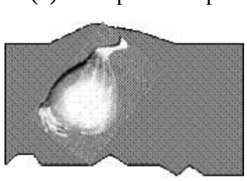
(a) Root portion down



(b) Root portion up



(c) Root portion horizontal



(d) Root portion inclined

Fig. 2 Different orientations of onion set

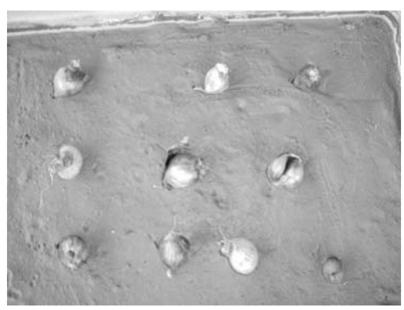


Fig. 3 Dropped onion sets collected on clay

growth. The experiment was a completely randomised design having four treatments and five replications. The four treatments were i) Planting root portion down, ii) Planting root portion up, iii) Planting root portion inclined and iv) Planting root portion horizontal. The crop growth parameters observed were i) Germination percentage at 3 DAP (Days after planting) and 7 DAP, ii) Plant height at 10 DAP and 24 DAP and iii) Number of shoots at 10 DAP and 24 DAP.

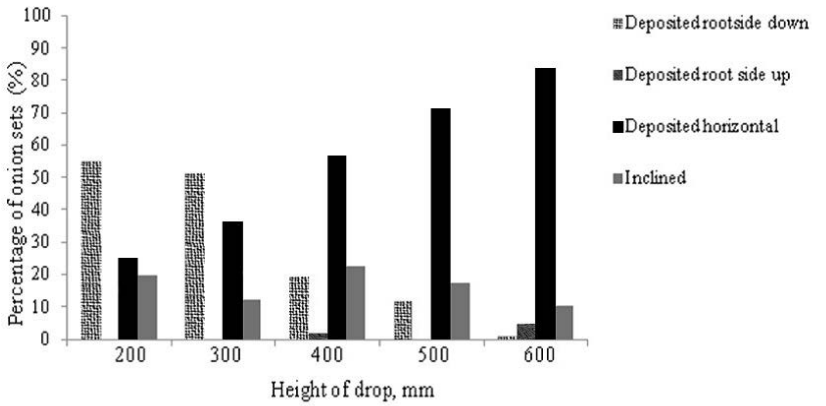


Fig. 4 Orientation of onion sets at deposition on soil − Initial position root side down

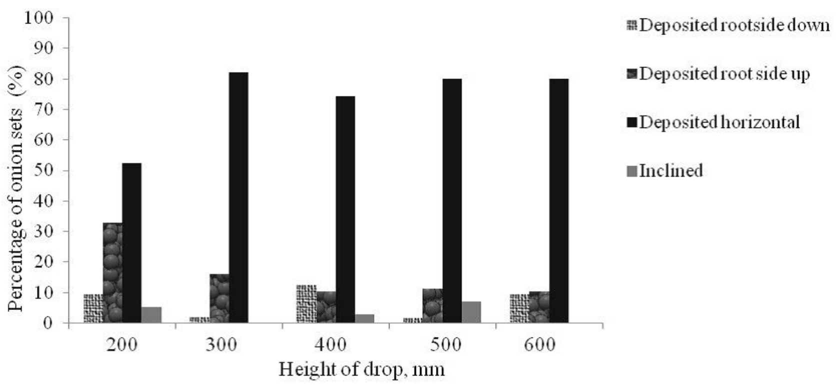


Fig. 5 Orientation of onion sets at deposition on soil − Initial position root portion up

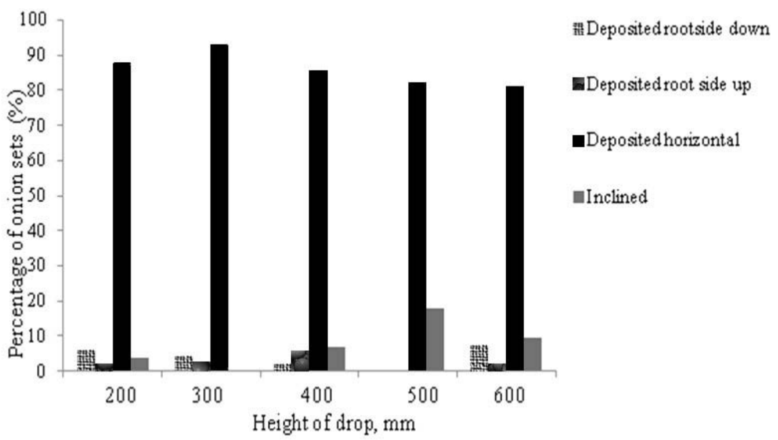


Fig. 6 Orientation of onion sets at deposition on soil − Initial position horizontal

Effect of Orientation of Onion Sets in the Onion Set Metering Disc at Delivery Point on Germination of Plant

After studying the different mechanism adopted for planting bold seeds (Singh, 1984); Mayande *et al.*, 2002; Sahoo and Srivastava, 2008) inclined plate metering mechanism was considered as metering mechanism for planting onion sets for the present study. The optimised metering disc for planting onion sets had 180 mm disc diameter, 10 equidistance cells (cell size 26 mm), fitted at an angle of 45° inside the hopper and had a peripheral speed of 14.13 m/min. The height of drop of onion set from the onion set planter will be 300 mm (Jiraporn *et al.*, 2010). The experiment was recorded by a video camera and the orientation of onion sets at delivery point of metering unit was observed for four grades of onions. The onion sets were graded into four grades based on weight as Grade − I: 2-3 g, Grade − II: 3-4 g, Grade − III: 4-5 g and Grade − IV: 5-6 g.

Results and Discussion

Depositing Orientation of Onion Sets

The deposited orientation of the dropped onion sets when dropped from five different heights namely 200 mm, 300 mm, 400 mm, 500 mm and 600 mm and maintained at three different initial position namely root portion down, root portion up and horizontal were presented in **Figs. 4-6**. There were four orientations on reaching the soil, that is i) root portion down, ii) root portion up, iii) horizontal and iv) inclined orientations. The results of different treatments on the orientation after reaching soil were analysed statistically. The results are discussed at three initial orientations.

Initial Orientation − Root Portion Down

From the statistical analysis, it was inferred that the height of drop had significant effect on the finally deposited orientation of onion set. **Fig. 4** shows that when the onion sets were dropped by having as root side portion down initially, the onion sets dropped from 200 mm height had the highest percentage of onion sets (55%) deposited as root side portion down, followed by 300 mm height (51%), 400 mm height (19%), 500 mm (12%) and 600 mm (1%). This implied that when the height of drop increased the onion sets did not maintain the initial orientation. The onion sets deposited as root portion up was the highest (6%) from the dropping height of 600 mm and it was 0-2% in all the other drop heights of 200 mm, 300 mm, 400 mm and 500 mm. Percentage of onion sets deposited as horizontal orientation was maximum (84%) at a dropping height of 600 mm, followed by 500 mm height (71%), 400 mm height (56%), 300 mm height (36%) and 200 mm height (25%). From the above observations, it was clear that when the height of drop was close to ground about 50% of the onion sets maintained the orientation as it was at rest (root portion down). When the height of drop increased, the onion sets tend to be deposited in horizontal position at reaching soil though they were maintained at root side portion down initially.

The height of drop in the planter would be 300 mm. When the onion sets were dropped having root portion down, there would be 51% root portion down, 36% horizontal, 12% inclined and 0% root side up orientation while depositing on soil.

Initial Orientation − Root Portion Up

The onion sets dropped from a height of 200 mm had the highest percentage of onion sets (33%) deposited as root portion up, followed by 300 mm height (16%), 400 mm height (10%), 500 mm (10%) and 600 mm (11%) (**Fig. 5**). This implied that when the height of drop increased the onion sets did not maintain the initial orientation and also decreased while increasing the height of drop during the free fall. The onion sets deposited as horizontal position ranged from 74% to 82% for the drop heights 300 mm, 400 mm, 500 mm and 600 mm. This implied that the onion sets would tend to be deposited as horizontal position at reaching soil though they were maintained at root portion up at initial orientation.

When the height of drop was 300 mm and the onion sets were dropped having root portion up at initial orientation would have 2% as root portion down, 16% as root portion up, 82% as root portion horizontal and 0% as root portion inclined orientation while depositing on soil.

Initial Orientation − Horizontal

The onion sets dropped from a height of 300 mm had highest percentage (93%) as horizontal position, followed by 400 mm height (86%), 500 mm height (82%) and 600 mm height (81%) horizontal position at reaching soil (**Fig. 6**). This implied that when the height of drop increased the onion sets did not maintain the initial orientation and also decreased while increasing the height of drop during the free fall.

When the height of drop was 300 mm and the onion sets were dropped having root portion horizontal at initial orientation would have 4% as root portion down, 2% as root portion up, 93% as root portion horizontal and 0% as root portion inclined orientation while depositing on soil.

Growth Parameters of Onion Sets While Planting at Different Orientations

Effect on germination of onion sets

The germination of onion sets were observed for 3 DAP (Days after planting) and 7 DAP and the results were analysed statistically.

The treatments had significant effect on the germination of the onion sets in both observations of 3 DAP and 7 DAP (**Fig. 7**). The onion sets planted at inclined orientation had the highest percentage of germination (100%) followed by those planted root portion down (80.2%), horizontal orientation (33.2%) and root side up (13.3%) on 3 DAP. However it was observed that the all the treatments except the treatment in which onion sets were planted root side up orientation had the 100 per cent germination 7 DAP (**Fig. 9**). From the above results it was inferred that the onion sets could be planted in any of the three orientations namely root portion down, horizontal orientation and inclined orientation.

Effect on number of shoots of onion plant

The number of shoots of onion plants were recorded at 10 DAP and 24 DAP for all the treatments and the observations were analysed statistically. The treatments had significant effect on number of shoots in both observations of 10 DAP and 24 DAP.

The onion sets planted inclined orientation had the highest number of shoots (19.4) followed by root portion down (18.6), horizontal orientation (17.8) and root portion up (0.2) on 10 DAP (**Fig. 8**). Whereas the highest number of shoots were observed for the onion sets planted root portion down (22.6) followed by root portion inclined orientation (22.4), horizontal orientation (22.2) and root portion up (3.4) on 24 DAP. However when the means were compared statistically by LSD method, it was inferred that the treatments planted root portion down orientation, inclined orientation and root portion inclined orientation had the highest of number of shoots and were on par.

A similar study conducted by Orlowski and Rekowska (1992) to investigate the effects of different clove sowing methods on garlic yield revealed that the clove bud pointed upward and bud pointed downward had the highest and lowest yield, respectively. Clove bud pointed either side and bud at any random position (similar to machine sowing) did not show any significant difference in yield.

Effect of orientation of onion sets in the onion set metering disc at delivery point on germination of plant

Percentage of onion sets oriented as root side up for the grade I, II, III and IV were 18.06, 13.93, 13.43 and 10.78 (**Fig. 9**). When the onion sets were dropped from a height of 300 mm maintaining root portion up orientation initially, 16% of onion sets were deposited having their root portion up orientation (**Fig. 5**). When the onion sets were planted root portion up, the germination percentage was 20% (**Fig. 7**).

From the above discussion, it was inferred that when 10.78 to 18.06% onion sets were dropped maintaining root portion up orientation initially, 2.25% onion sets would be deposited having root portion up orientation and out of 2.25% dropped onion sets, 0.5% onion sets will be germinating. By planting the onion sets by planter, there will be 98.25% germination where there is a possibility of 1.75% yield loss. However; there will be a saving of 30% on cost of planting by mechanical planter when compared to manual planting. Hence, the yield loss due to onion sets deposited as root portion up will be negligible.

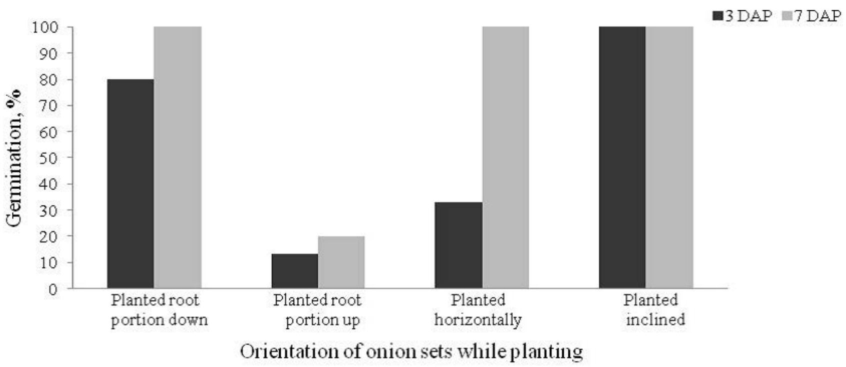


Fig. 7 Effect of planting orientation of onion sets on germination

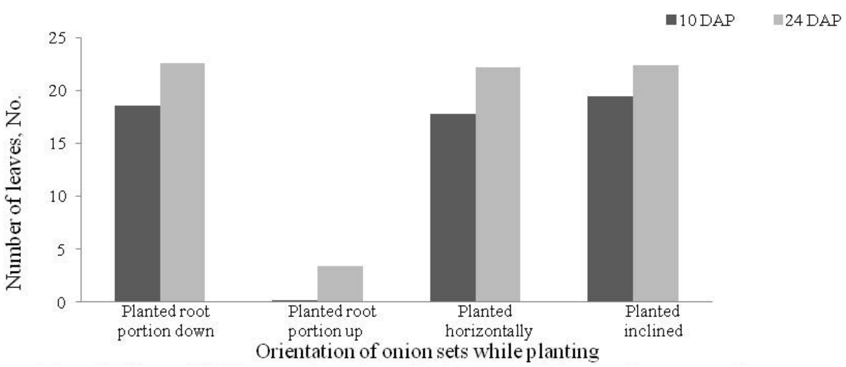


Fig. 8 Effect of different planting orientation of onion sets on number of shoots

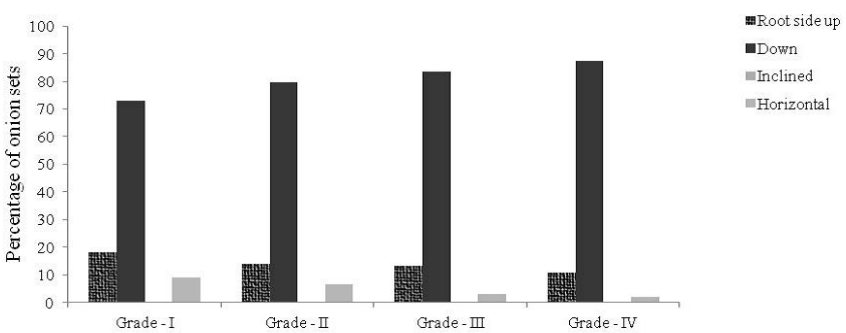


Fig. 9 Initial orientation of onion sets in the onion set metering disc for different grades

Conclusions

From the above study carried out to observe the depositing orientation of the onion set while reaching soil with reference to the three possible initial orientations of root portion down, up and horizontal at delivery point of a cell metering mechanism and five dropping heights of 200 mm, 300 mm, 400 mm, 500 mm and 600 mm, it was concluded that (i) About 2.25% of onion sets only will be deposited having root portion up orientation when reaching the soil which would have very less chance to germinate, (ii) There was 98% germination considering all four possible depositing orientation of onion sets, (iii) Hence an onion set planter to meter the onion sets without orienting the root portion down can be developed.

REFERENCES

Jiraporn, B., H. Sakurai and N. Ito. 2010. Design and control of metering system and furrow openers for garlic planter. International Agricultural Engineering Journal, 19 (2): 39-47.

Mayande, V. M., I. Srinivas, R. V. Adake and Y. Sreenivasulu. 2002. Investigations on groundnut planting accuracy and seed size using inclined plate planter. Indian J. Dryland Agric. Res. Dev., 17 (2): 158-163.

Orlowski, M. and E. Rekowska. 1992. Effect of the method of planting cloves on garlic yield. Zeszyty Naulowe Akademii Rolniczej-W-Szczecinie, Rolnictwo, 52: 65-77.
Singh, S. 1984. Design, development and evaluation of tractor drawn ridger planter for winter maize. Biennial Report, Dept. of Farm Power and Machinery, PAU, Ludhiana, India.
Sahoo, P. K. and A. P. Srivastava. 2008. Seed pattern characteristics of different metering systems for soaked okra seed. Journal of Agricultural Engineering, 45 (1): 1-6.

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A Contribution of Foam Separation Technique and Electro-Coagulation for Dairy By-Products Treatment

by

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Abstract

Electro-Sonic treatment of dairy industry wastewater was investigated using a combined system comprising of electro-coagulation and ultrasonication processing. Dairy industry wastewater is characterized by high chemical oxygen demand and other pollutants. The objective of this research was to investigate the effects of the investigated variables such as: applied current density of 1, 2, 4 and 6 mA/cm^2 which agrees 0.5, 1, 2 and 3A; processing times of 15, 30, 45, 60 and 75 minutes; initial protein concentrations of 100, 200 and 300 mg/L; ultrasonic frequency of 40 and 60 kHz; ultrasonic power of 100 and 200W and polarity changes state, with or without polarity change. For this purpose, rectangular aluminum anodes and iron cathodes were used in parallel within the separation column. Peripheral device was built to control the electrodes polarity. Six ultrasonic transducers were installed on the separation column wall in front of the inner electrodes from the three perpendicular dimensions. Bubbles created were categorized microscopically into two identities, microbubbles and nanobubbles. The bubble sizes in each identity were acknowledged into nominal groups according to their nominal diameter as a partial percent of the whole identity, which called intensity percentage of each group. The nominal groups of nanobubbles are 500, 800 and 1,100 nm. However, the microbubbles are 1,500, 2,100, 3,100 and 4,100 nm. As all the operating parameters potential of electrosonic device increase the intensity percentage of the bubbles of 500 and 1,500 nm were tend to be intensified, which interprets the removal potential of chemical oxygen demand was raised and able to achieve a 94.2% removal at a current density of 6 mA/cm^2, ultrasonic power of 200W, ultrasonic frequency of 60 kHz and change the electrode polarity every 30 seconds after 75 minutes of processing time which has removal efficiency index of 3,228.1 mg/kWh. The highest removal efficiency index of 5,013.3 mg/kWh can be obtained at electrical current of 1A (2 mA/cm^2); ultrasonic power of 100W; ultrasonic frequency of 60 kHz and with polarity change. Protein separation as another result was evaluated by recovery percent; enrichment and separation ratios. Generated bubble size in liquid phase and bubble coalescence and drainage in the foam phase are the major factors affect recovery, separation ratio and hence enrichment. Large bubbles lead into higher bubble drainage with less liquid holdup or less foam volume that has more protein content or concentrated, whereas smaller bubbles increase the surface area, which increase liquid holdup or higher foam volume or less concentration. The highest separation ratio of 54.16 obtained at electrical current of 0.5A, ultrasonic power 100W and frequency of 40 kHz. The tolerance among the three factors, bubble size, coalescence and drainage configures the optimal points of separation. The optimal points of foam separation were determined to be generally at ultrasonic power of 100W. The addition of ultrasonic to the electrocoagulation further increases the treatment efficiency. These results demonstrate the viability of coupled electro-coagulation with ultrasonication process as a reliable technique for pollutants removal from dairy processing wastewater.

Keywords: Dairy wastes treat-

ment; Protein separation; Chemical oxygen demand removal; Electro-coagulation; Ultrasonication; Combined technology; Bubbles sizing.

Introduction

The dairy industry is one of the most important industrial sectors. These vary in Egypt from small receiving stations to large processing plants where the most products made from milk are such as consumer milk, butter, cheese, yogurt, condensed milk, milk powder and ice-cream using processes such as bottling, pasteurization, filling in cans etc. In general, the volume of sewage generated in manufacturing facilities ranges from 0.2 to 10 L per liter of processed milk, which is one of the largest wastewater generators (Balannec *et al*., 2005). In most cases, these effluents are not treated and are simply thrown into River Nile or into one of its branches where they contribute to eutrophication by phosphorus and nitrogen compounds (Chimenos *et al*., 2006; Irdemez *et al*., 2006; Golder *et al*., 2006). Dairy effluents treating is thus of crucial importance not only for the environment, but also for the purpose of water recycling for industrial processes (Hamdani *et al*., 2005). The operational parameters determining efficacy of foam separation or fractionation, (bubble size, column height, height of foam layer, gas flow rate, and gas type) and protein solution conditions are known to affect the protein separation process (Banerjee *et al*., 1993 and Uraizee and Narsimhan, 1990). Electro-coagulation is an electrochemical technique that generates coagulants by dissolving electrically either aluminum or iron ions from electrodes into the solution. The metal ion creation happens at the anode, when the hydrogen gas is released at the cathode. The hydrogen gas succors in floating the suspended particles to the surface (Bazrafshan *et al*., 2013; Chen, 2004 and Adhoum *et al*., 2004). When an aluminum anode is used, the electrolytic dissolution of the aluminum anode produces cationic monomeric species such as Al^{3+} and Al $(OH)_2^+$, which are transformed initially into Al $(OH)_3$ and finally polymerized to Al_n $(OH)_{3n}$ according to the following equations (Mollah *et al*., 2001 and Torres-Sánchez *et al*., 2014):

$$Al_{(s)} \rightarrow Al^{3+}_{(aq)} + 3e^- \quad \text{.................Eqn 1}$$

$$Al^{3+}_{aq} + 3H_2O_{(l)} \rightarrow Al\,(OH)_{2(s)} + 3H^+_{(aq)} \quad \text{........Eqn 2}$$

$$nAl\,(OH)_3 \rightarrow Al_n(OH)_{3n} \quad \text{.... Eqn 3}$$

Oxidation of iron in an electrochemical process generation occurs through iron hydroxide, Fe $(OH)_n$, where n = 2 or 3. Two mechanisms have been proposed for the production of Fe $(OH)_n$:

$$4Fe_{(s)} \rightarrow 4Fe^{2+}_{(aq)} + 8e^- \quad \text{.......Eqn 4}$$

$$4Fe^{2+}_{(aq)} + 10H_2O_{(l)} + O_{2(g)} \rightarrow 4Fe\,(OH)_{3(s)} + 8H^+_{(aq)} \quad \text{Eqn 5}$$

Cathode:

$$8H^+_{(aq)} + 8e^- \rightarrow 4H_{2(g)} \quad \text{........Eqn 6}$$

Overall:

$$4Fe_{(s)} + 10H_2O_l + O_{2(g)} \rightarrow 4Fe(OH)_{3(s)} + 4H_{2(g)} \quad \text{......................Eqn 7}$$

Nomenclature	
COD	chemical oxygen demand, mg/L
REI	removal efficiency index of chemical oxygen demand, mg/kWh
WPC	with polarity change, state
OPC	without polarity change, state
C	electrical current, Ampere
F	ultrasonic frequency, kHz
P	ultrasonic power, Watt
IP	initial protein concentration, mg/L
SR	separation ratio, dimensionless
R	protein recovery percent, %
ER	enrichment ratio, dimensionless
Φ	objective value = SR × R
i	current density, mA/cm^2 of all anode electrodes surface area
A_{eff}	submerged area of the anode, m^2
EEC	electro-coagulation energy consumption, kWh
UEC	ultrasonic energy consumption, kWh
U	applied voltage, Volt
TEC	total energy consumption, kWh
V	treated water volume, liter
t	processing time, min
TECA	total energy consumption at ultrasonic power of 100W
TECB	total energy consumption at ultrasonic power of 200W
e	free electron
d_i	bubble diameter, nm
N	number of bubbles measured in the picture
Subscripts	
s	solid
aq	aqueous phase
g	gas
n	group units number
l	liquid
i	initial at zero minutes
f	final after 60 minutes
Superscripts	
+	positive charge
-	negative charge

The bubble size and its distribution are important factors affecting the separation of proteins. The separation ratio is defined as the concentration in the foamate divided by the concentration in the residue (Varley *et al.*, 1996 and Lambert *et al.*, 2003). Du *et al.* (2001) described the bubble size as a key for predicting the ability to separate proteins in a foam fractionation process. They reported that bubble size is affected by gas-liquid surface properties, such as pH, protein concentration, surface tension, and some operational parameters, such as the superficial gas velocity and sparger (diffuser) size. Saleh and Hossain (2001) determined the bubble size distribution in a foam fractionation column to identify the mechanism and design for foam fractionation process improvement. Wong *et al.* (2001) sized the bubbles in a continuous system to calculate the interfacial area and reported that the smaller bubbles, obtained at lower solution feed concentration, lower air velocities and pH adjacent to the isoelectric point, gave better protein enrichment. Leong *et al.* (2009) stated that the bubbles generated by the ultrasonic frequency of 20 kHz are relatively large and their collapse results in strong shockwaves which can be useful for mechanical shearing applications such as emulsification. However, Cho *et al.* (2005) reported that the nanobubbles generated by sonicating an aqueous solutions with two sided immersed palladium-coated electrode by a sonicator has a frequency of 20 kHz and output power of 200W were sufficiently stable and reproducible for measurements. The bubbles generated in the frequency range of 100 to 1000 kHz, are much smaller. However, their collapse induces a higher thermal energy which can be more useful for sonochemical purposes (Suslickand Crum, 1998). At above 1 MHz frequency, cavitational effects are much weaker. However, there are some industrial applications in this frequency range such as the gentle cleaning of electronic parts and liquids nebulization to create fine sprays (Leong *et al.*, 2011).

In this paper the main objective is to report the formation size of the bubbles in dairy effluents which were internally generated by both ultrasonication and electro-coagulation technologies under different operational factors. The process efficiency of foam separation technique was investigated by analyzing the effect of initial protein concentration, electrical density, polarity change state, ultrasonic frequency and its power on chemical oxygen demand, protein recovery percent and enrichment and separation ratios. The energy consumption was also considered.

Materials and Methods

The effect of combined bubble generator on the process efficiency of foam separation should be investigated for its importance. In this investigation, the influences of operational factors such as: applied current, with and without polarity changes, ultrasonic frequency and its power and initial protein concentration on the bubble size, which affect chemical oxygen demand (COD) removal, protein recovery percent and enrichment and separation ratios.

Combined Electro-Sonic Bubble Generator

The combined electro-sonic bubble generator consists of two bubble generation forms which were defined as ultrasonication and electro-coagulation processes. Bubbles were generated by sonicating the solutions with ten immersed electrodes of 50 mm wide × 100 mm long which were used for electro-coagulation process. Ultrasonic generator uses a magneto-restriction to dimensionally change the immersed electrodes and create the microbubbles. Ultrasonic energy was exerted by an electronic circuit schematically drawn by Proteus 8 program, **Fig. 1**, and manufactured by the aid of Future Electronics Company, Cairo at the Faculty of Engineering, Kafrelsheikh University which generates ultrasonic waves having a frequency of 40 and 60 kHz and an output power of up to 200W. The manufactured ultrasonic generator unit with six outputs was connected to six ultrasonic transducers (Bolt Clamped Transducer Dual Frequency 40/60 kHz) which were glued on the foam separation

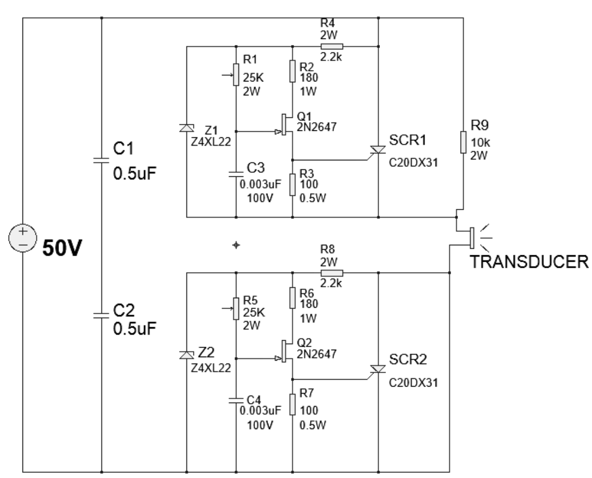

Fig. 1 Electronic circuit of ultrasonic generator with output of 200W and dual frequencies of 40 and 60 kHz

column wall for ultrasonic waves emit on both horizontal and vertical directions against the ten immersed electrodes. The electro-coagulation technique exploits the presence of ten immersed electrodes that are five aluminum anodes and five iron cathodes connected to a precision regulated direct current (DC) power supply (PS-8303D2) with a bipolar connection. The geometric area of all anode electrodes in contact with the solution was 500 cm^2. Tests were conducted with 1, 2, 4 and 6 mA/cm^2 of all anode electrodes surface area current density which results in 0.5, 1, 2 and 3A and voltage source of 30V as set by (Torres-Sánchez *et al*., 2014 and Bazrafshan *et al*., 2013). The polarity of the electrodes was swapped every 30 seconds, in order to avoid pollutants accumulation between the electrodes. Two alternatives of electro-coagulation treatment were investigated, the first one under changeable polarity (WPC) and the other without alteration of polarity (OPC). The polarity changes were made by Arduino Boarduno from Future Electronics Company, Cairo. To monitor degradation, multiple samples (100 mL) were collected every 10 minutes. Every aqueous sample was filtered using a filter of 0.2 μm for fixed solids exclusion before sonication. The Chemical Oxygen Demand (COD) were analyzed with a spectrophotometer (PG instruments, T80+, UV/VIS Spectrometer, Germany).

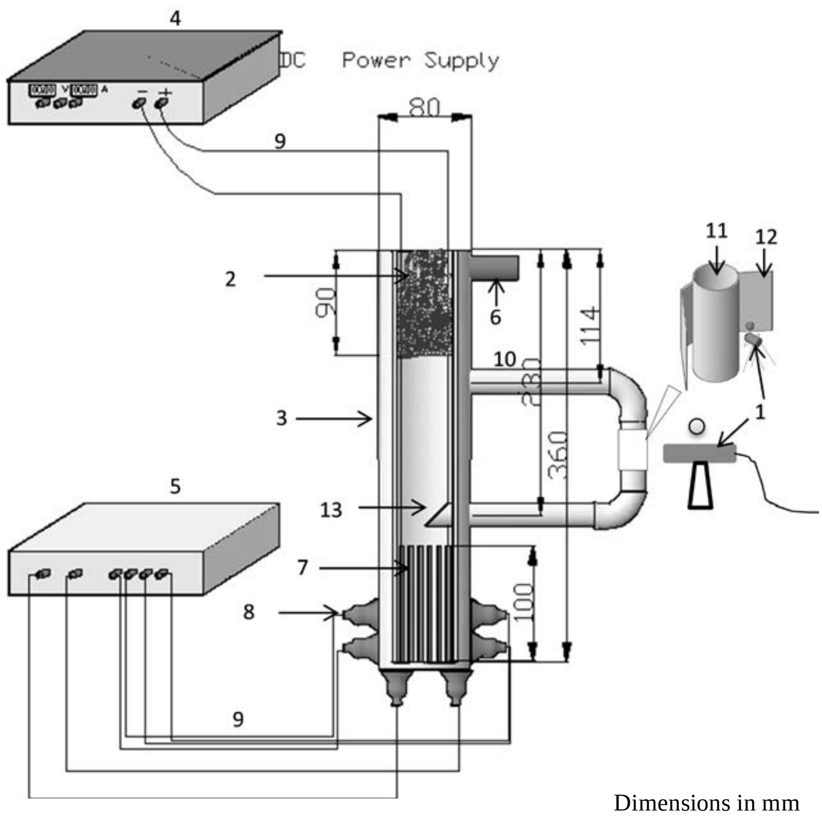

Fig. 2 Experimental setup of combined foam separation unit: (1) digital microscope USB PC with fluorescent 40W lamb, (2) generated foam, (3) foam separation column, (4) DC power supply regulator, (5) ultrasonic generator, (6) 12.5 mm in diameter foam collection tube, (7) electro-coagulation bipolar aluminum and iron electrodes in parallel connection, (8) ultrasonic transducers, (9) connecting wires,(10) 12.5 mm in diameter PVC entering tube, (11) acrylic transparent tube in front of digital microscope, (12) white board behind the acrylic tube, (13) 12.5 mm in diameter recirculating tube with a chamfered end which aids to evacuate all water inside the transparent tube for continuous replacement

Micro and Nanobubbles Size Measurement

The size of bubbles was measured by taking photographs with a digital Microscope (500X - USB PC) with a 60 mm objective lens placed about 11 cm from the separation column (Wong *et al*., 2001). The arrangement for bubbles photography, for real time monitoring in the foam separation column, consists of feeding horizontal tube, transparent vertical tube with a white board installed posteriorly and 12.5 mm in diameter recirculating horizontal tube with a chamfered end which aids to evacuate all water inside the transparent tube for continuous replacement. The photographs were used with about 45° indirect reflection from a white back zone (Wong *et al*., 2001). The photograph was taken at the middle of the liquid section of separation column. For scaled measurements a 3.57 mm in diameter steel bead, held in place with a thin (1.5 mm in diameter) wire, was placed at the same section of the separation column. The positions of the steel ball, the camera and the cross-section of photograph, in the separation column, are shown in **Fig. 2**. Fluorescent-microscope with camera with objective magnification up to 1000X was used for smaller bubble identification, and the bubble size determination was measured by taking the average of three captured photos. The pictures of bubbles were transferred into a computer. The diameter of the bubbles was then measured using Image Analysis Software, Image J (National Institute of Health, Maryland, USA). The experimental setup of combined foam separation apparatus was constructed and installed in the Agricultural Engineering Department, Faculty of Agriculture, Kafrelsheikh University, Kafr Elsheikh Governorate, Egypt during the Autumn season of 2015.

The mean diameter (d_{32}) of the bubbles was calculated using the following equation (Du *et al*., 2001):

$$d_{32} = \frac{\sum_{i=1}^{N} d_i^3}{\sum_{i=1}^{N} d_i^2}$$ ....Eqn 8

Where N is the number of bubbles measured in the picture. Bubble size was measured at the start of a run. In a single picture, about 120-248 bubble size measurements were obtained. Bubble size was determined for various combinations of ultrasonic frequencies, initial protein concentration, and electrical power.

Performance Evaluation of Foam Separation Process

The foam separation process performance can be described by protein recovery percent (R), enrichment ratio (ER) and separation ratio (SR). The separation ratio quantifies the concentration degree that happens and the recovery shapes how much of the protein is recovered. The initial protein concentrations were prepared by a bovine serum albumin from 100 to 300 mg/L in distilled water was used as model protein solutions. The initial pH of the solutions was of 6.0 ± 0.1. The foam collected in the beaker was stirred manually to help collapse it and stored at 4°C (for 12 h) for further collapse before analysis. The processing time, for an experimental run, was definite as the time when the first foam drop entered the foam collector. All experimental runs were carried out at an ambient temperature of (24 ±1°C). The protein concentration was measured by spectrophotometer at a wavelength of 280 nm (Brown *et al.*, 1990 and Aksay and Mazza, 2007), and calculated by using a standard curve of the bovine serum albumin (Brown *et al.*, 1990). The foam separation process performance was evaluated by measurement of the protein enrichment ratio Equation 9 and protein recovery, Equation 10, is defined as the mass of bovine serum albumin in the foamate (fully separated foam) divided by the mass of bovine serum albumin initially in the bulk fluid. An objective value (Φ) was defined as Φ = SR × R to determine the operating conditions for optimal foam separation process (Noel *et al.*, 2002).

All the following equations are defined by Aksay and Mazza, 2007 as follows:

The enrichment ratio can be described as;

ER = (Protein concentration in foamate) / (Protein concentration of the initial solution).................Eqn 9

Protein recovery percent is calculated by;

R = (Protein concentration in foamate × V_{fomate}*) / (Protein concentration of the initial solution* × $V_{initial}$*)* × *100*..........................Eqn 10

The separation ratio is calculated as;

SR = (Protein concentration in foamate) / (Protein concentration of residual solution in the column) ....Eqn 11

Current density (i, A/m^2) can be calculated with the equation;

$i = C / A_{eff}$ ....Eqn 12

Where A_{eff} is the submerged area of the anode, m^2

The electro-coagulation energy consumption, *EEC*

$EEC = (U \times C \times t) / (60 \times V)$ .....Eqn 13

The ultrasonic energy consumption, *UEC*

$UEC = (P \times t) / (60 \times V)$ ....Eqn 14

Where *U* is the applied voltage, V; t is the processing time, minutes, P is the ultrasonic power, Watt and V is the volume of the treated water, liter.

So the total energy consumption, *TEC*

$TEC = EEC + UEC$ ....Eqn 15

The removal efficiency index can be calculated by the following formula:

$REI = (COD_i - COD_f) / TEC$..Eqn 16

Results and Discussion

Bubble Size Distribution

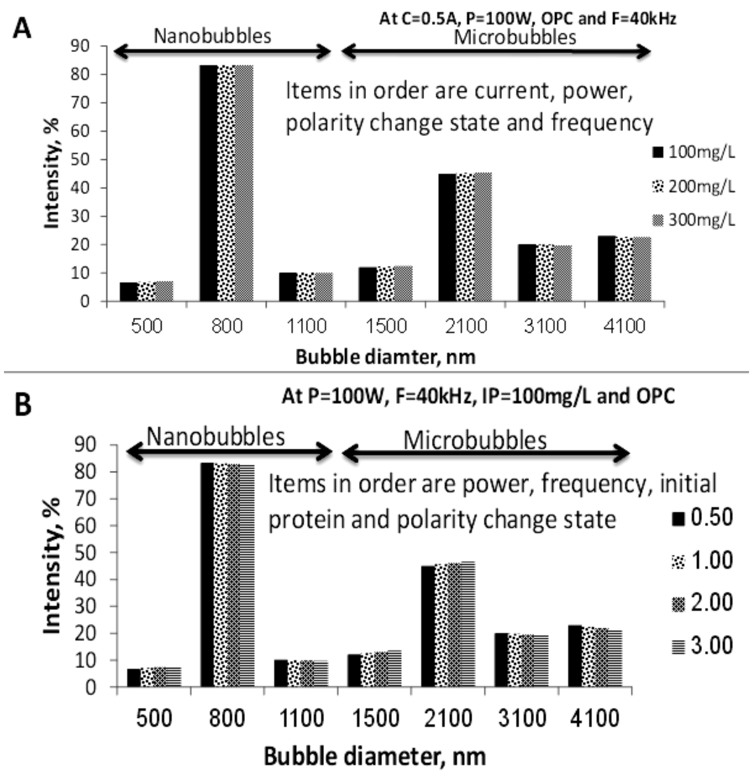

Fig. 3 The effect of initial protein concentration (A) and electrical current (B) on bubble size distribution generated as microbubbles or nanobubbles by a combined electro-coagulation with ultrasonication for bubble generator

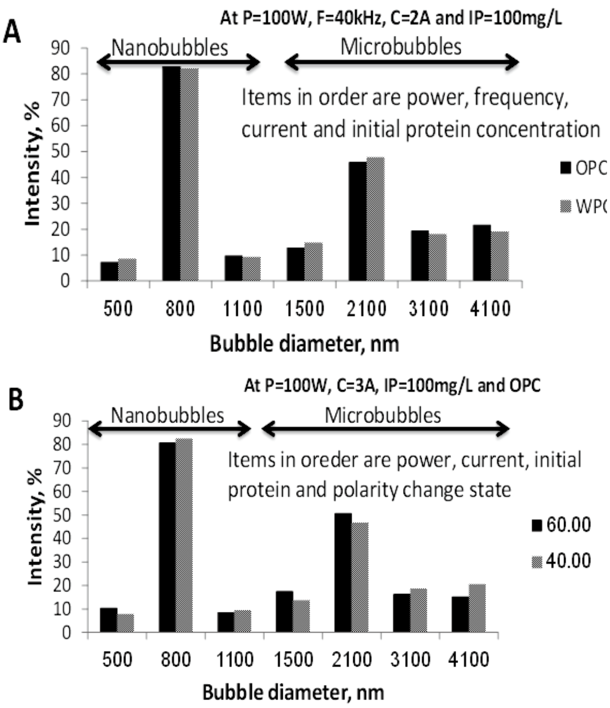

Fig. 4 The effect of polarity change state (A) and ultrasonic frequency (B) on bubble size distribution generated as microbubbles or nanobubbles by a combined electro-coagulation with ultrasonication for bubble generator

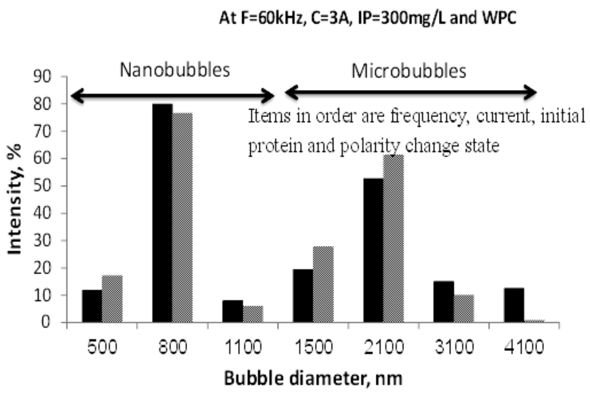

Fig. 5 The effect of ultrasonic power on bubble size distribution generated as microbubbles or nanobubbles by a combined electro-coagulation with ultrasonication for bubble generator

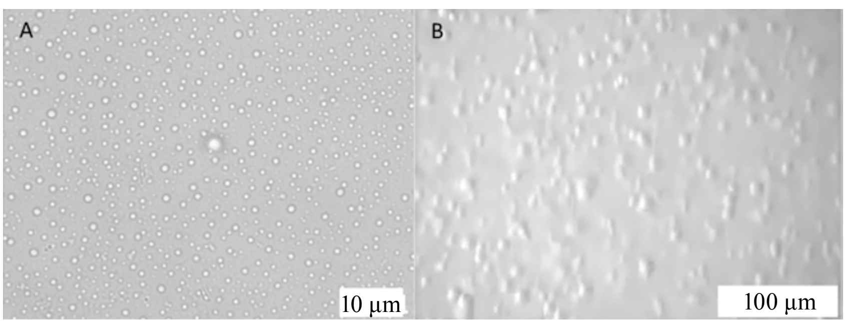

Fig. 6 Captured photos by optical microscope with magnification up to 1,000X (A) and by a digital microscope (B) connected to laptop with USB connection with magnification of 500X for real time monitoring

Fig. 3A shows the effect of initial protein concentration on bubble size distribution of microbubbles, generally generated by electro-coagulation processing constituent that were recognized by USB digital microscope **Fig. 6B**, which are divided into four sets of 1,500, 2,100, 3,100 and 4,100 nm and the nanobubbles, mostly created by ultrasonication processing constituent that were visualized by optical microscope **Fig. 6A**, are allocated into three different groups of bubble sizes of 500, 800 and 1,100 nm. The intensity percent distribution of nanobubbles and microbubbles is slightly affected by initial protein concentration. As initial protein concentration rises from 100 to 300 mg/L, the intensity percent of nanobubbles sizes of 800 and 1,100 nm decreases from 83.33 to 83.17% and from 10.02 to 9.92%, respectively. However, the bubble size of 500 nm intensifies from 6.65 to 6.91%. In the same behavior, the microbubble sizes of 1,500 and 2,100 nm intensity percent also increase, like the bubble size of 500 nm. On the other hand, the bubble sizes of 3,100 and 4,100 nm diminish from 20 to 19.74% and from 23 to 22.5%, respectively. The intensification increment of some bubble sizes group in one identity is diminishing the intensification of other bubble sizes groups. It can be concluded that the bubble size of 500 nm of nanobubbles group and the bubbles sizes of 1,500 and 2,100 nm of microbubbles group are the major indicators of system efficacy response. From the results above it can be inferred that the generated nano and microbubbles of lower sizes slightly intensify as initial protein concentration increases due to the surface tension lessening caused by protein concentration that aids smaller sizes creation by both of electro-coagulation and ultrasonication constituents. Those results are in agreement with (Cho, *et al.*, 2005 and Aksay and Mzza, 2007). By investigating the effect of electrical current on bubble size distribution, it is noticed that the size distribution of bubbles generated tends to be smaller for both categories of nano and microbubbles as shown in **Fig. 3B**. As the intensity percent of the smallest bubbles increases, the efficacy of foam separation process exaggerates.

Fig. 4A shows the effect of polarity change state on bubble size distribution tends to increase the intensity percentage of bubble sizes of 500 nm of nanobubbles group and 1,500 and 2,100 nm of microbubbles group. This result can be explained by the fact that in without polarity change state (OPC), the aluminum plates act as sacrifice electrodes, resulting greater corrosion and as a result the generation of ion leakage increases. Additionally, the formation of an oxide layer on the surface of the cathode contributes to a decreased effectiveness of the overall process (Torrez-Sanchez *et al*., 2014). As illustrated by **Figs. 4B** and **5**, the ultrasonication treatment (frequency and power) has higher effect than others of current and initial protein concentration, where the intensity percent of the bubbles of 500 nm increases from 7.91 to 10.56% of nanobubbles groups and the others of microbubbles are increased from 13.76 to 17.58% and from 46.82 to 50.77% of bubbles sizes of 1,500 and 2,100 nm, respectively, when the ultrasonic frequency increases from 40 to 60 kHz. The effect of ultrasonic power was observed obviously that is shown by **Fig. 5**. As ultrasonic power increases from 100 to 200W, the intensity percent of nanobubbles sizes of 500 nm increases from 11.88 to 17.19% even if the nanobubbles sizes of 800 and 1,100 nm declines from 80.04 to 76.71% and from 8.07 to 6.10%, respectively. So these runs of experiments show that the bubbles of both categories tends to be smaller as the ultrasonic power rises from 100 to 200W, frequency upsurges from 40 to 60 kHz and electrical current upturns from 0.5 to 3A.

Chemical Oxygen Demand and Removal Efficiency Index

Chemical oxygen demand, COD was investigated at different electrical currents, **Fig. 7**. It can be seen that with the increasing in electrical current, the COD drops. The COD was reduced to 784, 545, 398 and 266 mg/L in 30 minutes at electrical currents of 0.5, 1, 2 and 3A, respec-

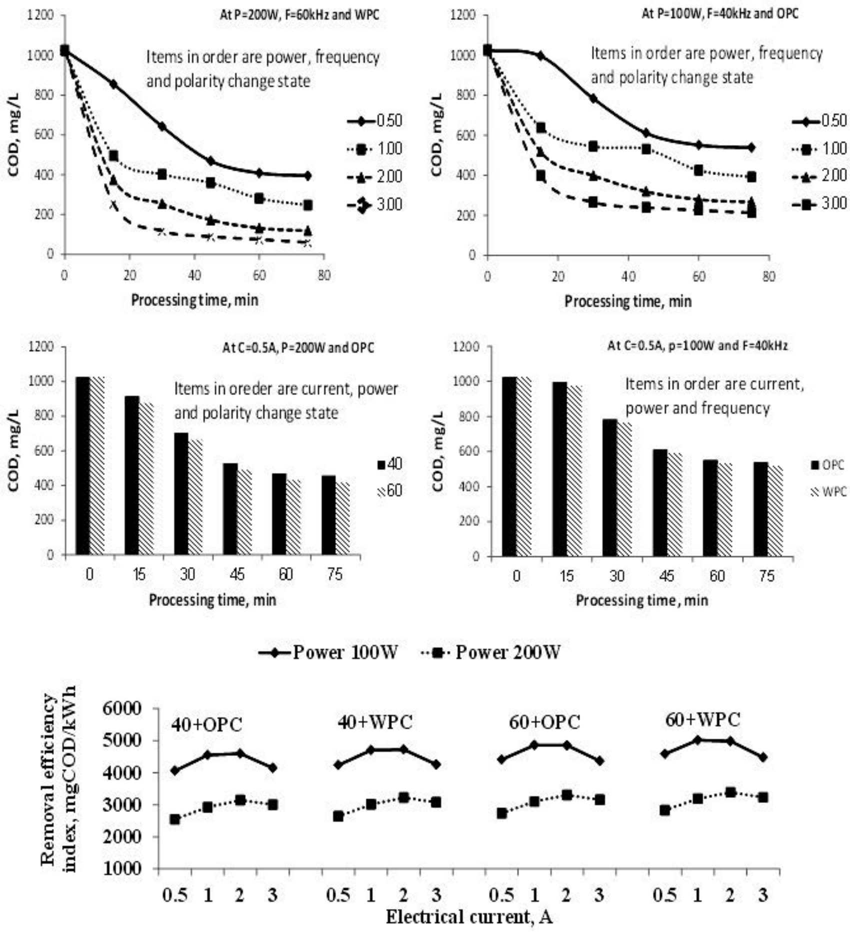

Fig. 7 The effect of electrical current, polarity changes and ultrasonic frequency on COD diminution and efficiency index at two different operating conditions of combined electro-coagulation with ultrasonication processing unit

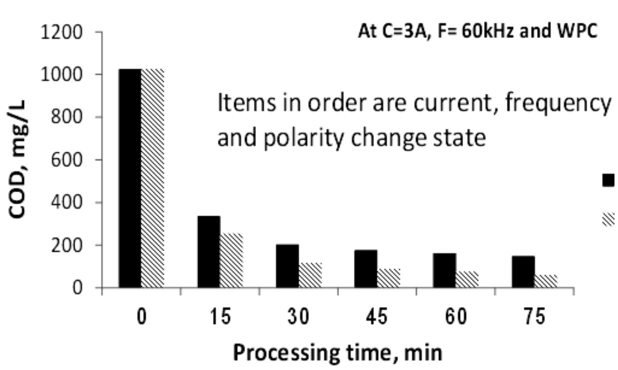

Fig. 8 The effect of ultrasonic power on COD abatement of combined electro-coagulation with ultrasonication processing unit

tively, which were further reduced to 538, 392, 267, 213 mg/L in 75minutes. The COD reductions were due to the increase in aluminum cations and polymeric hydroxide cations which combines with negative ions in the waste solution which finally neutralizes and forming a heavy mass which settled down. Removal efficiency index, REI was differs in its response to the same operating conditions where the REI of ultrasonic power of 100W was higher than that of 200W. The highest REI achieved was 5,013.34 mg/kWh at electrical current of 1A, 100W, 60 kHz and with polarity change state.

It can be observed in the **Figs. 7** and **8** that the final COD obtained after 75 minutes of processing time at four levels of electrical current of 0.5, 1, 2 and 3A decreases from 538 to 395 mg/L, 392 to 247 mg/L, 267 to 119 mg/L and 213 to 60 mg/L, respectively. This abatement effect was due to the bubbles generated by sonication effect on the electrodes which aids to release any tiny pollutants on their surfaces. This manifest was owed to the bubbles generated by sonic energy might oscillate with the sound frequency. At an instant during sonic compression phase, bubbles might suddenly collapse to a fraction of their maximum size. The gas inside a bubble might be thus compressed and adiabatically heated. Under certain conditions, an imploding shock wave might be driven by collapsing bubble walls, which could increase the temperature and create a rather destructive environment, and thus often used in erosion of electrode surface (Cho *et al.*, 2005). Other reason of COD falls by ultrasonic effect was the ultrasound energy would be immediately transformed into the work of cohesion by forming bubble and its surface. This process might be composed of the creation of surface, evaporation of gases to fill vacuoles, and the adsorption of impurities from waste solution.

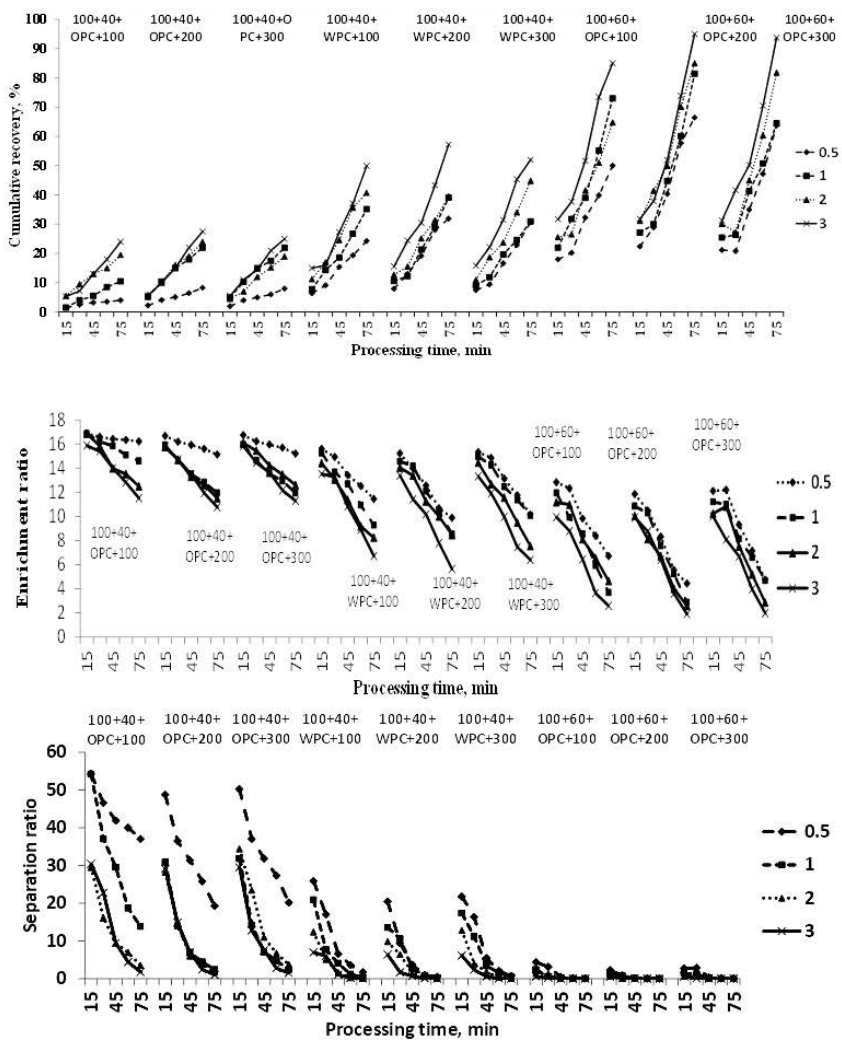

Fig. 9 Effect of electrical current on the cumulative recovery percent and enrichment and separation ratios at different treatments; Items in order of all curves legends are ultrasonic power, W + ultrasonic frequency, kHz + polarity change state, with polarity change state WPC or without OPC + initial protein concentration, mg/L

Protein Recovery Percent and Enrichment and Separation Ratios

The effect of electrical current at different treatments of ultrasonic power, frequency, polarity change state and initial protein concentration on protein recovery percent and enrichment and separation ratios can be seen in **Fig. 9**. The enrichment and separation ratios are found to be higher for lower current values, ultrasonic power and frequency and the without polarity changes for electrodes. Separation ratio has the same behavior as such of the enrichment ratio. The bubbles as a result are smaller with a high liquid content lead onto lower enrichment and separation ratios values (Uraizee and Narsimhan, 1996 and Swamy *et al.*, 2010). The bubble size is not the only determinate of the interfacial area where protein carrying occurs, but also coalescence and drainage in the foam phase (Du *et al.*, 2003). Larger bubbles lead onto bigger drainage, and hence less liquid holdup, while the smaller bubbles enhance the superficial surface area. This means that lower ultrasonic and electrical power increase the bubble size which as a smaller capacity for protein adsorption (Hossain and Fenton, 1998).

When the initial protein concentration increases from 100 to 200 mg/L at ultrasonic power of 100W, frequency of 40 kHz, without polarity change state and electrical current of 3A, cumulative recovery percent increases from about 24 to 28%. Further increase in the initial protein concentration causes a decrease in the cumulative recovery percent from about 28-25%. An increase in the initial protein concentration produced a more stable foam and hence a holdup of more liquid in the foam and thus increases cumulative recovery percent but decreases both the enrichment and separation ratios. The enrichment ratio of a 300 mg/L protein solution, 40 kHz, without polarity change state and an electrical current of 3A increases from 1.8 to 11.3 when only the ultrasonic power drops from 200 to 100W, declines the protein recovery percent from 97 to 25%, **Fig. 10**, due to two reasons, one owe to the bubble size; the larger bubbles decreases the foam flow rate and, hence, enhances the enrichment and separation ratios. The other is indebted in electrodes cleanness, the ultrasonic and polarity change state are installed in this experiment to keep the electrodes uncontaminated or fresh, more impurities on electrodes leads to less recovery percent of protein.

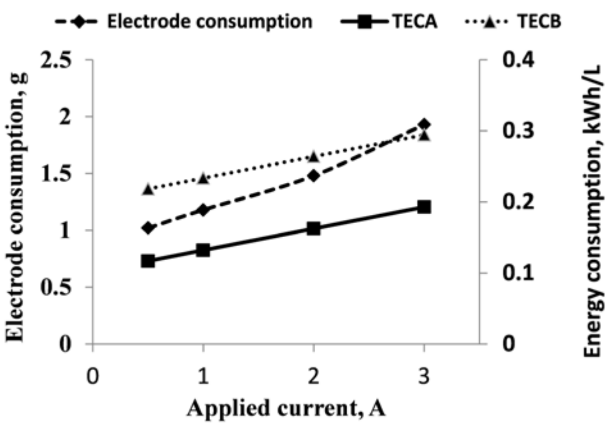

Fig. 10 Total energy consumption of electro-coagulation with ultrasonic power level of 100W (TECA) and level of 200W (TECB) and electrode consumption during the treatment process (processing time = 75 min) under different applied currents

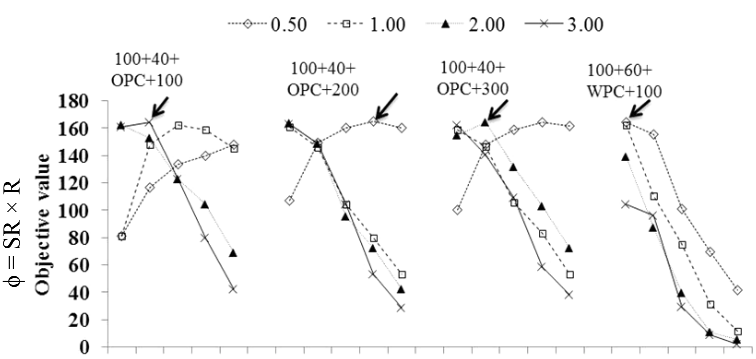

Fig. 11 Optimal points of foam separation process under different operating conditions, arrows point the optimal point of separation process for the highest four experimental runs; Items in order for all curves legends are ultrasonic power, W + ultrasonic frequency, kHz + polarity change state, with polarity change WPC or without OPC + initial protein concentration, mg/L

Energy and Electrode Consumption

Electrical energy consumption is a very important tool in the electro-coagulation process. It can be embedded from **Fig. 10** that the higher the applied current of the system, the higher the weight of the electrode consumed. It means that an increase in the applied current causes a proportional increase of the electrode consumption. This result is in agreement with those of Bayar *et al.*, 2011 and Bazrafshan *et al.*, 2013.

The highest objective value Φ obtained was at ultrasonic power of 100W, ultrasonic frequency of 40 kHz, without polarity change state, initial protein concentration of 200 mg/L and electrical current of 0.5A achieved after 60 minutes of treatment beginning as shown in **Fig. 11**. However the second highest objective value Φ occurred at electrical current of 2A which obtained after 30 minutes of processing initialization. The difference between these two values is relatively small. To determine which condition is better, it must first be decided if one would like to recover a high concentration or more volume. If neither is more important than the other, the condition with the lowest energy consumption would be preferred to lessen energy costs. The lowest energy consumption was of 0.115 kWh for the highest objective value. However, for the second highest objective value, the energy consumption was of 0.13 kWh.

Conclusions

Sharing the emerging technologies individually or in union with the other known technologies is the important tool to develop food processing wastes treatment. Ultrasonic combined with electro-coagulation used in foam separation columns was investigated to treat dairy wastes. The bubbles, generated in the separation column by both electro-coagulation and ultrasonication, were gauged. Initial protein concentration has the lowest effect on bubble size distribution. However, the ultrasonic power has the highest impact. The best bubble size distribution percent of nanobubbles obtained was 17.2, 75.7 and 6.1% for 500, 800 and 1,100 nm respectively and of microbubbles was of 27.8, 61.4, 10 and 0.79% for 1,500, 2,100, 3,100 and 4,100 nm, respectively at initial protein concentration of 300 mg/L, electrodes polarity was changed every 30 seconds, electrical intensity of 6 mA/cm^2, ultrasonic power 200W and frequency of 60 kHz. However, at this established operating parameters, the total energy consumed records the highest value of 0.2944 kWh/L of dairy waste. And so on the chemical oxygen demand removal was the highest, whereas chemical oxygen demand removal efficiency index was achieved at different set of operating parameters at electrical current of 1A (2 mA/cm^2); ultrasonic power of 100W; ultrasonic frequency of 60 kHz and with polarity change state. The performance of foam separation column was investigated. Protein recovery percent increases as bubble size decreases. Maximum protein recovery percent of 99.1% was obtained at the best bubble size distribution percent that was described above. An increase in the initial protein concentration produces a more stable foam and hence a holdup of more liquid in the foam and thus increases cumulative recovery percent but decreases both the enrichment and separation ratios. At 300 mg/L protein solution, as the ultrasonic power decreases from 200 to 100W, the enrichment ratio increases from 1.8 to 11.3 and the protein recovery percent declines from 97 to 25%. Separation ratio starts to diminish dramatically to be 4.41 as ultrasonic frequency increases from 40 to 60 kHz. These results were due to two reasons, one owe to the bubble size, i.e., the larger bubbles decrease the foam flow rate and, hence, enhances the enrichment and separation ratios. The other is indebted in electrodes cleanness, the ultrasonic and polarity changes were used to keep the electrodes uncontaminated or fresh, more impurities on electrodes leads to less recovery percent of protein. The optimum operating conditions was determined based on the desired balance among protein recovery percent and enrichment and separation ratios. Objective value, is the separation ratio and protein recovery percent product, shows that the optimum point of ultrasonic power of 100W, ultrasonic frequency of 40 kHz, without polarity change state, initial protein concentration of 200 mg/L and electrical current of 0.5A achieved after 60 minutes of processing time.

REFERENCES

Adhoum, N., L. Monser, N. Bellakhaland and J. E. Belgaied. 2004. Treatment of electroplating wastewater containing Cu2+, Zn2+ and Cr (VI) by electrocoagulation, Journal of Hazardous Materials,112 (3): 207-213.

Aksay, S. and G. Mazza. 2007. Optimization of protein recovery by foam separation using response surface methodology, Journal of Food Engineering, 79: 598-606.

Balannec, B., M. Vourch, M. Rabiller-Baudry and B. Chaufer. 2005. Comparative study of different nanofiltration and reverse osmosis membranes for dairy effluent treatment by dead-end filtration. Sep Purif Technol., 42: 195-200.

Banerjee, R., R. Agnihotri and B. C. Bhattacharya. 1993. Purification of alkaline protease of Rhizopusoryzae by foam fractionation. Bioprocess Engineering, 9: 248-255.

Bayar, S., Y. Y. Sevki, A. E. Yilmazand and S. İrdemez. 2011. The effect of stirring speed and current density on removal efficiency of poultry slaughterhouse wastewater by electro-coagulation method. Desalination, 280 (1-3): 103-107.

Bazrafshan, E., H. Moein, F. K. Mostafapour and S. Nakhaie. 2013. Application of electro-coagulation process for dairy wastewater treatment, Journal of Chemistry, Hindawi Publishing Corporation Volume 2013, Article ID 640139, 8 pages.

Brown, L., G. Narsimhan and P. C. Wankat. 1990. Foam fractionation of globular proteins. Journal of Biotechnology and Bioengineering, 36: 947-959.

Chen, G. 2004. Electrochemical technologies in wastewater treatment. Sep Purif Technol, 38: 11?41.

Chimenos, J. M., A. I. Fernandez, A. Hernandez, L. Haurie, F. Espiell and C. Ayora. 2006. Optimization of phosphate removal in anodizing aluminum wastewater. Water Res., 40: 137-143.

Cho, S. H., J. Kim; J. Chun and J. Kim. 2005. Ultrasonic formation of nanobubbles and their zeta-potentials in aqueous electrolyte and surfactant solutions. Colloids Surfaces A: Physicochem. Eng. Aspects, 269, 28-34.

Du, L., A. Prokop and R. D. Tanner. 2003. Effect of ph on the startup of continuous foam fractionation process containing ovalbumin. Separation Science and Technology, 38 (5): 1093-1109.

Du, L., Y. Ding, A. Prokop and R. D. Tanner. 2001. Measurement of bubble size distribution in protein foam fractionation column using capillary probe with photoelectric sensors. Applied Biochemistry and Biotechnology, 91?93: 387-404.

Golder, A. K., A. N. Samanta and S. Ray. 2006. Removal of phosphate from aqueous solutions using calcined metal hydroxide sludge wastewater generated from electro-coagulation. Sep Purif

Technol., 52: 102-109.
Hamdani A., M. Mountadar and O. Assohei. 2005. Comparative study of the efficacy of three coagulants in treating dairy factory waste water. Int J Dairy Technol., 58: 83-88.
Hossain, M. M. and G. Fenton. 1998. Concentration of proteins from single component solution using a semi-batch foaming process. Journal of Separation Science and Technology, 33 (11): 1703-1721.
Irdemez, S., N. Demircioglu, Y. Sevki and Z. Bingul. 2006. The effects of current density and phosphate concentration on phosphate removal from wastewater by electro-coagulation using aluminum and iron plate electrodes. Sep Purif Technol., 52: 218-223.
Lambert, W. D., L. Du, Y. Ma, V. Loha, V. Burapatana, A. Prokop, R. D. Tanner and N. B. Pamment. 2003. The effect of pH on the foam fractionation of betaglucosidase and cellulase. Bioresource Technology, 87: 247-253.
Leong, T., M. Ashokkumar and S. Kentish. 2011.The fundamentals of power ultrasound – a review. Acoustics Australia, 39 (2): 54-63.
Leong, T. S. H., T. J. Wooster, S. E. Kentish and M. Ashokkumar. 2009. Minimizing oil droplet size using ultrasonic emulsification. Ultrason. Sonochem., 16 (6): 721-727.
Mollah, M. Y. A., R. Schennach, Parga and D. L. Cocke. 2001. Electro-coagulation (EC), Science and Application. J Hazard Mater, 2001B, 84: 29-41.
Noel, J. A. Prokop and R. D. Tanner. 2002. Foam fractionation of a dilute solution of bovine lactoferrin. Applied Biochemistry and biotechnology, 98-100: 395-402.
Saleh, Z. S. and M. M. Hossain. 2001. A Study of the separation of proteins from multicomponent mixtures by semi-batch foaming process. Chemical Engineering and Processing, 40: 371-378.
Suslick, K. S. and L. A. Crum. 1998. Sonochemistry and sonoluminescence, in Handbook of Acoustics, M. J. Crocker, Editor, Wiley Interscience: New York, PP: 243-253.
Swamy, J. N., C. L. Crofcheck and M. P. Mengüç. 2010. Polarized light based scheme to monitor column performance in a continuous foam fractionation column. Journal of Biological Engineering, 4(5): 1-10.
Torres-Sánchez, A. L., S. J. López-Cervera, C. de la Rosa, M. Maldonado-Vega, M. Maldonado-Santoyo and J. M. Peralta-Hernández. 2014. Electro-coagulation process coupled with advance oxidation techniques to treatment of dairy industry wastewater. International Journal of Electrochemical Science, 9: 6103-6112.
Uraizee, F. and G. Narsimhan. 1990. Foam fractionation of proteins and enzymes. II. Performance and modelling. Journal of Enzyme Microbiology and Technology, 12: 315-316.
Uraizee, F. and G. Narsimhan. 1996. Effects of kinetics of adsorption and coalescence on continuous foam fractionation of proteins: comparison of experimental results with model predictions. Biotechnology and Bioengineering, 51 (4): 384-398.
Varley, J., A. Kaul and S. Ball. 1996. Partition of protein from binary mixtures by a batch foaming process. Biotechnological Techniques, 10: 133-140.
Wong, C. H., M. M. Hossain and C. E. Davies. 2001. Performance of a continuous foam separation column as a function of process variables. Bioprocess and Biosystem Engineering, 24: 73-81.

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Development of a Damping System for Reversible Mouldboard Plows Using Multiple-Criteria Decision Analysis

by

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Abstract

Reversible moldboard plows are often equipped with a wheel assembly that is used to adjust the working depth and help the device in transportation. This research is focused on optimization of the wheel assembly to solve the problem of deformation and hydraulic system damages caused by crash of wheel and plow body when rotating at the head lands. For this purpose, brain-storming raised five primary ideas which one of them considered as final idea during a multi-criteria decision making process. Vibration tests of optimized plow showed that the mechanism was successful in reducing the crash energy up to ten times.

Keywords: Moldboard plows; Damper; Optimization; Vibration; Design

Introduction

Reversible moldboard plow is one of the most common equipment used in primary tillage operation in many countries (Buckingham, 1976). These machines are equipped with a wheel assembly which turns when rotating in the head lands of the farm and results in a severe crash between wheel assembly and the plow body. Some problems associated with mentioned crash are: Harsh sound, deformation of the plow body, and damage of the tractor hydraulic system.

In mechanical systems, such impacts and crashes can be traced and mesured as vibration in diffrent points of the machine body. But in agricultral machinary filed most studies in vibration analysis are addresed to the tractor and engine powered machines. There are many intresting and beneficial studies in this field.

(Hostens *et al.*, 2000) designed a six-degrees-of-freedom test rig to

Fig. 1 Schematic view of the primary design of moldboard plow used in the research

study tractor vibrations under controlled laboratory conditions. It was indicated that a frequency range from 1 Hz with amplitude of 10 cm to 10 Hz with amplitude of 1 mm could be excited as ultimate test rig performance criteria. It was further reported that the test rig was ready to be used as an important tool for more accurate, more controllable and repeatable simulation and validation test tool to gain an insight into sprayer boom behavior, human comfort and suspension development. Vibration and impact is also important in tractor seat. A set of experiments on a spring equipped seat versus a seat equipped with an on-off damper indicated that a simple damping system can reduces 40% of vibration root-mean-square (RMS) (Duke and Goss, 2007).

Due to the widespread application of moldboard plows in tillage operation and regarding problems associated with the reversible moldboard plows, this research is focused on optimization of the wheel assembly and evaluation of the introduced mechanism in damping the impact, however applied approach can be beneficially employed in solving different problems in this area.

Materials and Methods

The moldboard plow used in this project was GAK-RG3 made by Ghataat Ahangari Khorasan Co., (**Fig. 1**). Its main parts are 3 point hitch connecting frame, the main frame, mouldboards, and wheel assembly (**Figs. 2** and **3**). The wheel assembly has three tasks:

1) help the implement while transporting
2) prevention of excessive weight transfer while working and
3) adjust working depth.

Wheel assembly is located at the end of main frame through a flange (part No. 1). The butterfly part (Part No. 3) can slide horizontally and adjust working depth with the help of two screw (part No. 2). At the headlands, wheel can rotate a maximum 270° and curved leg (part No. 7) seat on the other side through a pin (part No. 6).

Preliminary Ideas to Solve the Problem

In order to find an appropriate solution for the mentioned problems, following four ideas were raised during couple of brainstorming meetings.

Coulomb damper:

the first and simplest idea was to damp the momentum energy by connecting a helical or disk spring to the moving components of the wheel assembly using a frictional disk (**Fig. 4**).

Torsional damper:

Although these devices are not

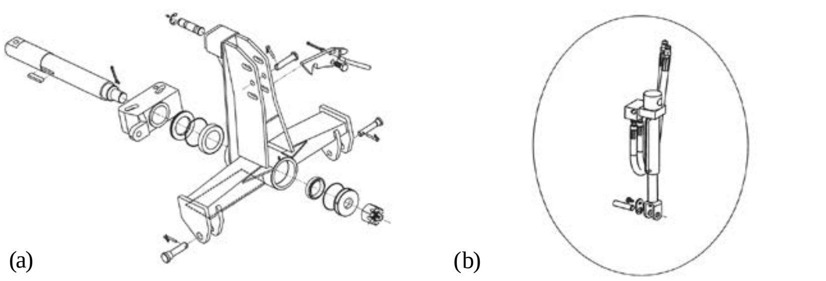


Fig. 2 a) Implement connecting frame for mounting to the tractor three point hitch b) hydraulic cylinder used for reversing the plow

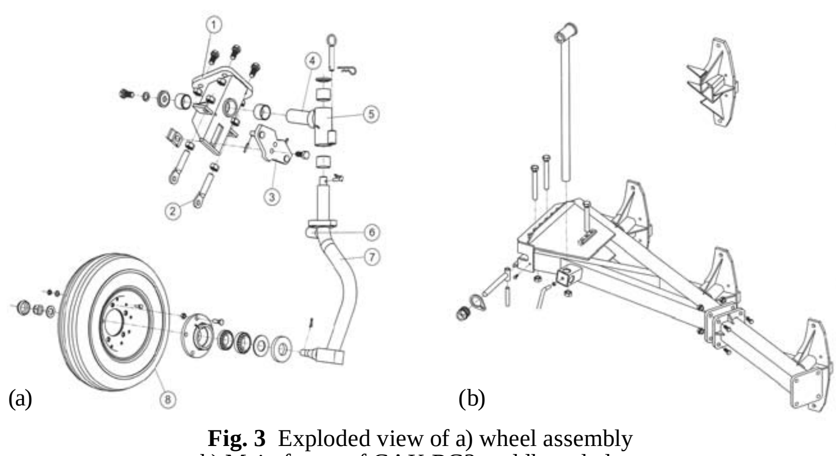


Fig. 3 Exploded view of a) wheel assembly b) Main frame of GAK-RG3 moldboard plow

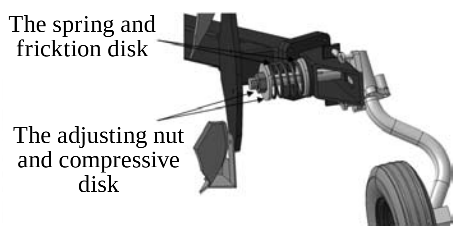


Fig. 4 Schematic view of coulomb damper idea

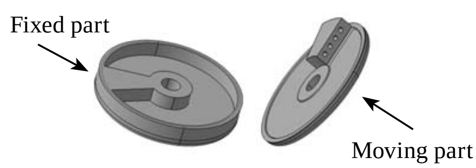


Fig. 5 Torsional damper

very low cost and easily available, but torsional dampers can potentially decrease the energy of impact by placing between wheel assembly and plow body (**Fig. 5**).

Rack and pinion mechanism:

Linear dampers (shock absorbers) in terms of availability, diversity, durability, and price have some advantages in comparison to torsional dampers. A rack and pinion mechanism can be a solution in adapting the rotational movement of wheel assembly with linear damper (**Fig. 6**).

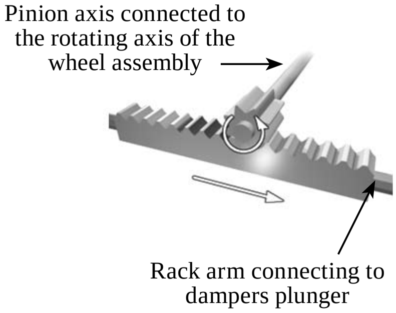


Fig. 6 Rack and pinion mechanism

Fig. 7 Schematic view of the crank and slider mechanism

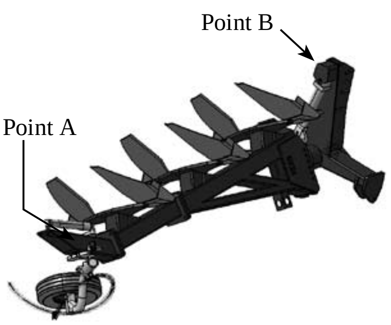


Fig. 8 Schematic view of the plow showing the points A and B

Crank and slider mechanism:

As mentioned in the rack and pinion idea, all of the benefits of the linear dampers could be used if the rotational motion is converted to linear. Employing a crank and slider mechanism is another idea can have some advantages in comparison with rack and pinion (**Fig. 7**).

Multi-criteria Analysis

Researchers employed different engineering methods to design and optimize agricultural machines (Ortiz-Laurel and Roessel-Kipping, 2014; Vatsa and Singh, 2014; Kate *et al*., 2015; Shirwal *et al*., 2015; Jethva and Varshney, 2016). While each of them has their own advantages, but choosing an appropriate approach will help to find the best solution.

One of the most produced attention steps of an engineering design process is theoretical assessment of creative ideas. In this research, a multiple-criteria decision analysis (MCDA) process was employed to find the most appropriate idea and optimize primary design of the plow (Kylili *et al*., 2016).

The first step of the MCDA is specifying a number of assessment criteria regarding the problems that should be resolved by each idea. In this step, some criteria were specified for assessment of superiority of each idea with respect to the others. The specific time and place of conditions for manufacturing process and also target market's interests were important parameters for specifying the assessment criterions.

The assessment criteria considered in this research are:

1) Appearance factors (Aesthetics, simplicity, and proportionality of components).
2) Producibility,
3) Total production costs,
4) Low and easy maintenance,
5) Energy damping ability,

Assigning a 'weight' to each criterion is the second step. In fact, the weight of a criterion expresses the priority of the criterion with respect to the others (**Table 1**).

In this table, the '+' symbol in each cell indicates that the criterion in each row is more important than the criterion of related column. 'r' is the number of '+' signs in each row, 'n' is the total number of '+' signs in the table, and the ratio of 'r/n' is defined as the relative weight of the criterion.

As the third step, the scores assigned to ideas against each criterion. Results of this process are given in **Table 2**. In these tables, the 'r/n' ratios in each row indicate the relative scores of the ideas.

Finally, calculating the total weighted score for each idea was the last step and the idea with most total weighted score (Crank and slider idea) considered as the best (**Table 3**).

Aftre choosing an appropriate shok absorbor, a vibration test was carried out at the points A and B which are marked in **Fig. 8**. Point A was choosen because it is close to the crash pint and point B were clos-

Table 1 Relative weight of criteria

Criteria	Appearance	Producibility	Production costs	Maintenance	Damping	r	r/n
Appearance			+			1	0.11
Producibility	+		+			2	0.22
Production costs						0	0
Maintenance	+		+			2	0.22
Damping	+	+	+	+		4	0.44
						n = 9	1

est poit to the tractor lifting arm.

Peak value is one of the most frequently used indexes to describe such impacts and defined as the maximum positive or negative value of the vibration wave. Root mean square (RMS) of the vibration signal as well as crest factor are the two other indexes which are used to study modification results. Crest factor is defined as the ratio of peak value to RMS value of the waveform (Thomas, 1982).

vibration signal were recorded using a vibration test device (Time TV 300) while its working range was 0.1-392.0 m/s^2 with an accuracy of ±5%. The data were gathered in real condition (rotating the plow in farm headland) with and without the shock absorber.

Table 2 Scores of ideas against the criteria

	Idea	A	B	C	D	r	r/n
Appearance	A		+			1	0.2
	B					0	0
	C	+	+		+	3	0.6
	D		+			1	0.2
						n = 5	1
Producibility	Idea	A	B	C	D	r	r/n
	A		+	+	+	3	0.5
	B			+		1	0.17
	C					0	0
	D		+	+		2	0.33
						n = 6	1
Production costs	idea	A	B	C	D	r	r/n
	A		+	+	+	3	0.5
	B			+		1	0.17
	C					0	0
	D		+	+		2	0.33
						n = 6	1
Maintenance	Idea	A	B	C	D	r	r/n
	A					0	0
	B	+				1	0.17
	C	+	+			2	0.33
	D	+	+	+		3	0.5
						n = 6	1
Damping	Idea	A	B	C	D	r	r/n
	A					0	0
	B	+				1	0.2
	C	+				1	0.2
	D	+	+	+		3	0.6
						n = 5	1

The alphabetical codes assigned to the ideas, A: Coulomb damper; B: Rack and pinion; C: Torsional damper; D: Crank and slider

r: The number of '+' signs in each row

n: Total number of '+' signs for each criterion

r/n: Score of each idea against the criterion

Table 3 Weighted scores of ideas for each criterion

	Coulomb damper	Rack and pinion	Torsional damper	Crank and slider
Appearance	0.11 × 0.20	0.11 × 0.00	0.11 × 0.60	0.11 × 0.60
Producibility	0.22 × 0.50	0.22 × 0.17	0.22 × 0.00	0.22 × 0.33
Production costs	0.00 × 0.50	0.00 × 0.17	0.00 × 0.00	0.00 × 0.30
Maintenance	0.22 × 0.00	0.22 × 0.17	0.22 × 0.33	0.22 × 0.50
Damping	0.44 × 0.00	0.44 × 0.20	0.44 × 0.20	0.44 × 0.60
Total weighted score	0.132	0.162	0.226	0.468

Results and Discussions

Wheel assembly before and after modification is shown in **Fig. 9**. As mentioned vibration test was carried out in order to study responce of modified the system while occurring an impact. Examples of the vibration waveform collected at the points A and B (**Fig. 8**) of primary and modified design of the wheel are shown in **Fig. 10**.

RMS and peak values at the points A and B are illustrated in **Fig. 11**. As shown, damping mechanism caused RMS reduction at the points A and B, 9.97 and 8.04 times respectively. As well as 10.97 and 8.50 times reduction in peak value

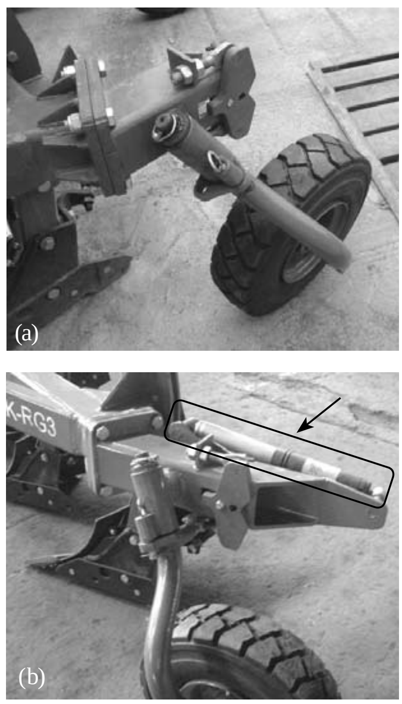
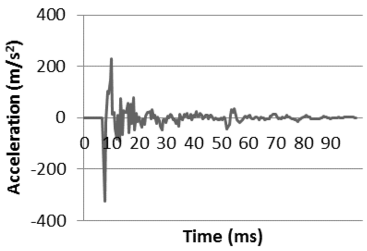


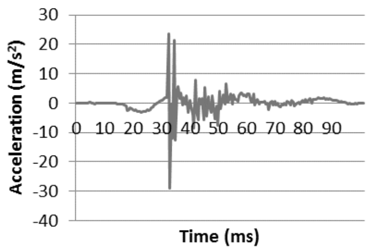
Fig. 9 a) Wheel assembly before modification
b) modified wheel assembly with mounted damper

can be seen at the points A and B respectively.

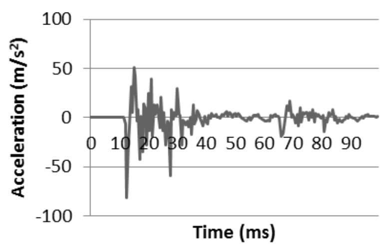
According to the results illustrated in **Fig. 12**, the mechanism does not have significant effect on the crest factor, as RMS and peak values were reduced in almost equal ratios. Slight reduction of the crest factor means that the damping mechanism not only reduced the peak value but also all components of the vibration waveform at different frequencies. Analysis of the results obtained through the vibration tests showed 8 to 11 times reduction in RMS and peak value of the vibration signal by modification of the wheel assembly.



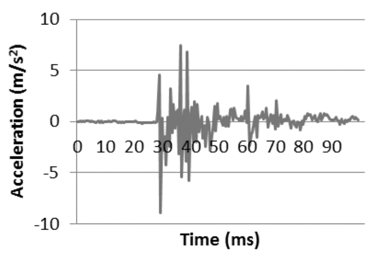
Vibration of point A with the damping mechanism



Vibration of point A without damping mechanism



Vibration of point B with the damping mechanism



Vibration of point B without damping mechanism

Fig. 10 Examples of vibration signals picked up at points A and B of the plow frame with and without the use of the damping mechanism

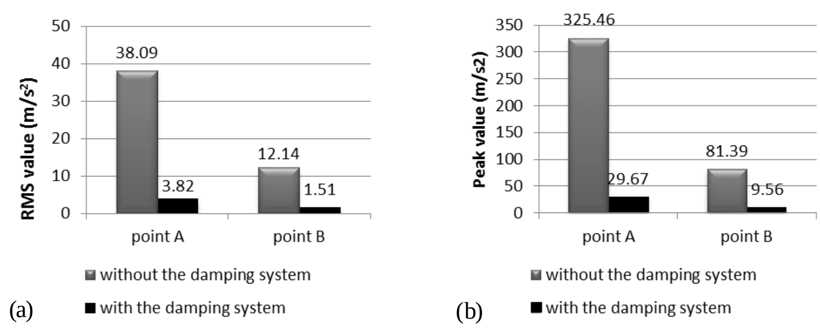


Fig. 11 RMS and peak values of the vibration signal at points A and B

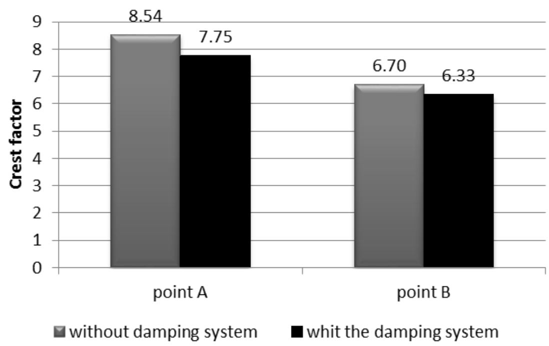


Fig. 12 Comparison of the mean of Crest factor of vibration signal at points A and B

Conclusions

In this research, an engineering design process was done to modify and improve wheel assembly of a reversible moldboard plow. Some creative ideas were filtered in a multi-criteria decision analysis process and the plow frame was modified based on chosen idea. Vibration test showed that modfication has resulted to a significant reduction in RMS and peak values of the vibration signals picked up from the plow frame while slight reduction of the crest factor revealed that the damping mechanism uniformly reduces all components of the vibration signal in different frequencies. Althuogh primary farming impeliments such as moldboard plows are designed many years ago and improved several times but regarding their wide seprate application there are enogh justification to continue study and modification in menttioned field.

Acknowledgment

Special thanks are due to the Ghataat Ahangari Khorasan Co. for providing the instruments and test facilities of this research.

REFERENCES

Buckingham, F. 1976. FMO: Fundamentals of Machine Operation: Tillage. Deere

Duke, M. and G. Goss. 2007. Investigation of tractor driver seat performance with non-linear stiff-

ness and on-off damper. Biosyst Eng 96: 477-486
Hostens, I., J. Anthonis, P. Kennes and H. Ramon. 2000. PM─Power and Machinery: Six-degrees-of-freedom Test Rig Design for Simulation of Mobile Agricultural Machinery Vibrations. J Agric Eng Res 77: 155-169
Jethva, K. R. and A. K. Varshney. 2016. Design and Development of Reciprocating Type Cumin Cleaner Cum Grader. AMA, Agricultural Mechanization in Asia, Africa and Latin America 47: 8
Kate, A. E., N. C. Shahi, U. C. Lohani and J. P. Pandey. 2015. Development and Testing of Pedal Operated Wild Apricot Pit Grader. AMA, Agricultural Mechanization in Asia, Africa and Latin America 46: 48-52
Kylili, A., E. Christoforou, P. A. Fokaides and P. Polycarpou. 2016. Multicriteria analysis for the selection of the most appropriate energy crops: the case of Cyprus. Int J Sustain Energy 35: 47-58
Ortiz-Laurel, H. and D. Roessel-Kipping. 2014. Development of a mechanical harvesting aid for prickly pear cactus fruit.
Shirwal, S., I. Mani, N. P. S. Sirohi and A. Kumar. 2015. Development and Evaluation of Carrot Harvester. AMA, Agricultural Mechanization in Asia, Africa and Latin America 46: 28-34
Thomas, D. W. 1982. Effect of intermodulation and quasi-periodic instability in the diagnosis of rolling element incipient defect. J. Mech. Des. 1041297:
Vatsa, D. K. and S. Singh. 2014. Development and Evaluation of Power Tiller Operated Zero Till-Drill for Mechanizing Wheat Sowing in Hills. AMA, Agricultural Mechanization in Asia, Africa and Latin America 45: 86

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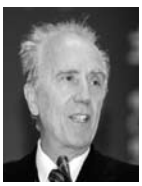

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Currently smartPA in Urban Agriculture towards a smartPlanet competing with Climate Change, and commercialised developments in Fisheries, Animals, large scale Precision Fertile Irrigation, Greenhouses, Hydroponics and special food products. He attained the title of High-end Int’l Expert of China and prepares 2 Int’l patent files on improving the Water and Energy footprints of Modern Agriculture.

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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.

1464

Growth of Draught Animal Power in Madhya Pradesh of India: An Inter-regional Analysis: K. P. Saha, Sr. Scientists, Central Institute of Agricultural Engineering, Bhopal, INDIA, kpsaha@ciae.res.in; **Dushyant Singh**, same; **V. Bhushana Babu**, Scientist (Sr. Scale), same

The study was undertaken to examine the growth of draught animal power (D.A.P.) availability in different agro-climatic zones of Madhya Pradesh. The results obtained from the analysis of collected secondary data indicates that there exists a declining trend of growth in availability of D.A.P. owing to a negative growth rate observed in most of the agro-climatic zones. In many agro-climatic zones of Madhya Pradesh, the projected future availability of D.A.P. becomes negligible and wiped out due to the higher initial availability of D.A.P. as compared to the carrying capacity. The prospective zones for promotion of improved animal drawn equipment may be Chhattisgarh Plain, Northern Hill Region of Chhattisgarh, Satpura Plateau, Nimar Plateau and Jhabua Hills. However, it is also a most challenging task to design and develop suitable animal drawn implements matching to the short sized and less powerful bullocks available in Kaymore Plateau and Satpura Hills and Northern Hill Region of Chhattisgarh areas.

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1469

Self-Grooving Rubber Roller: A Substitute to Chrome Composite Leather Roller in Double Roller Cotton Ginning Machine: V. G. Arude, Scientist (Sr. Scale) (FMP), Central Institute for Research on Cotton Technology, ICAR, Mumbai -400019, INDIA; **T. S. Manojkumar**, Program Coordinator (KVK) and Senior Scientist (ASPE), Central Plantation Crops Research Institute, ICAR, Kasargod, INDIA; **S. K. Shukla**, Senior Scientist and Officer In-charge, (Mech. Engg.), Ginning Training Centre of Central Institute for Research on Cotton Technology, ICAR, Nagpur -440023, INDIA

Self-grooving rubber roller as substitute to chrome composite leather roller for use in ginning machine was developed. Self-grooving rubber roller was made out of rubber discs of hard and soft rubber compound prepared in a specially designed die by moulding technique. Roller was made with nitrile rubber having radial layers of softer rubber compound to form grooves. Compounding ingredients in appropriate proportion were added to provide sufficient hardness, temperature resistance, and to ensure effective ginning. Self-grooving rubber roller was tested on commercial double roller (DR) gin. Roller speed of 40 rpm was found to be optimum to achieve efficient ginning without any adverse effect on fibre and seed quality as against 100 rpm for leather roller. Gear box of the conventional DR gin was suitably modified to run at 40 rpm. Ginning performance of self-grooving rubber roller in terms of capacity, energy consumption, effect on fibre quality and cost economics was studied and compared with the leather roller. Use of the self-grooving rubber rollers was found to increase the productivity of the DR gin by 25 to 30%. Periodical grooving and drudgery involved in grooving operation in leather roller was eliminated in rubber roller which consequently resulted in reduction in machine downtime up to 2 hours/day. Energy consumption was found to be 15 to 18% lower and working like of the rubber roller was estimated to be 3,000 h as against 1,000 h in leather roller. Rubber roller is eco-friendly roller and there is no environmental pollution and health hazard to workers as there is no chromium contamination while ginning. It was observed that one time investment on the modification in DR gin can be paid back within a period of 65 working days of 20 h.

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1473

The Determination of the Most Suitable Seed Pelleting Thickness in Sugar Beet According to the Case of Emergence Irrigation and Different Sowing Distances: Koc Mehmet Tugrul, Turkish Sugar Factories Corporation, Directorate of Sugar Institute, 06930 - Etimesgut, Ankara, TURKEY; **Sevki Buzluk**, same; **Aysegul Boyacıoglu**, same; **Rıza Kaya**, same; **Seref Gurkan**, same

The research was conducted to find the optimal seed calibration for sugar beet cultivation in Turkey. The research is planned to be two emergency irrigation subjects (A1, A2), 8 and 17 cm seed distances in row (B1, B2) and naked and pelleted seed calibration (C1-C7) in order to be able to compare different circumstances. In conclusions, the highest beet and refined sugar yield and digestion values were found in 8 cm seed distance in row with naked sugar beet seed and applied emergency irrigation. Also, planting pelleted seeds ranging from 3.50 to 4.25 mm calibration can be said to be the most accurate application.

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1476

The Potential of Spectroradiometry Measurements to Estimate Biophysical and Biochemical Properties of Beans Crop: Adel M. H. Elmetwalli, Faculty of Agriculture, University of Tanta, Tanta, EGYPT; **Andrew N. Tyler**, School of Biological and Environmental Sciences, University of Stirling, Stirling FK9 4LA, UK; **Peter D. Hunter**, same

Non-destructive monitoring of agricultural crops becomes more important to improve crop productivity. In site specific management, in-situ remotely sensed data is of significant importance for quantifying nitrogen deficiency and salinity stress effects on crops. In the reported research, the visible and near infrared portions of the electromagnetic spectrum were used to derive vegetation indices sensitive to nitrogen deficiency and salinity stress in beans (Phaseolus Vulgaris, L). Four nitrogen fertilization rates (0, 30, 60 and 100 kg/ha) and three water salinity levels (1.5, 3 and 5 dS/m) were used to subject plants to both stressors. Reflectance measurements were collected from beans plants under artificial illumination conditions at different growth stages and used to calculate 45 commonly used vegetation indices for predicting beans properties. Strong significant correlations between beans properties and different vegetation indices were observed. Crededge and R750/R700 ratio were found to be the optimum indices for predicting beans chlorophyll content (r = 0.657). R710/R760 ratio was also found to be the optimum index for predicting beans biomass (r = -0.582). PSNDb was found to be sensitive to beans grain yield (r > 0.595). The correlations with grain yield were found to be strongest at the R6 growth stage.

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1479

Potential of Farm Mechanization in North Western Himalayan State Uttarakhand of India: **Sukhbir Singh**, Sr. Scientist (FMP), Division of Agril. Engg., I.I.S.R., Lucknow - 226 002 (U.P.) INDIA; **Shankar Singh**, Asstt. Professor, Marathwada Institute of Technology, Bulandshahr (U.P.) INDIA

Uttarakhand is situated in North Western Himalayas of India blessed with naturally occurring micro agro-climatic regions suitable for cultivation of a wide range of agri-horticultural crops with a great potential for development. But the level of farm mechanization in the state is very poor with respect to mechanical power, efficient implements, water management, renewable energy and post harvest technology sectors. The undulating topography, small and irregular size fields, lack of skilled manpower, poor facilities of repair and maintenance, poor purchasing power of farmers and non-availability of improved farm implements and machines are some of the main reasons for low level of mechanization in the hilly region of the state. Immediate attention of the state government and other funding agencies is required to strengthen the agricultural engineering wing in hills of Uttarakhand to handle the farm mechanization problems. Despite various constraints, there is a great scope for increasing productivity of land and farmer's economy through creation of small water resources for irrigation, land development, use of efficient gender friendly farm power and implements, rain water harvesting, disseminating renewable energy gadgets and introducing small scale agro based industries employing post harvest engineering principles.

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1622

Evaluating a Screw Press for Extracting the Oil of Rapeseed: Armin Kohan, Assistant Professor, Department of Agricultural Machinery, Shoushtar Branch, Islamic Azad University, IRAN, Kohan.armin@gmail.com

The effect of three factor that is pre-heating temperature (T in °C) at four levels, screw rotational velocity (N in rpm), at three levels and nozzle diameter (D in mm) at three levels and each with three replications were used to investigate the percent oil extraction from rape seed. An apparatus was developed as shown in Figure 1. A factorial experiment in the form of a Completely Randomized Design was used. Duncan's Multiple Range Test at 5% level was used for further analysis. The highest mean percent of oil extraction was 29.43% at a rotational velocity of 40 rpm and a nozzle size of 10mm in every temperature. Under these conditions, pre-heating had no significant effect on the percent oil extracted. The lowest mean of oil extraction was 20.71% at a rotational velocity of 50 rpm, a nozzle size of 15 mm and pre-heating temperature of 20°C.

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1636

Evaluation of Pre-Cleaners for Processing of Machine Picked Cotton in India - A Case Study: **S. K. Shukla**, Sr. Scientist & OIC, Ginning Training Centre, ICAR- CIRCOT, Nagpur- 440023, INDIA; **P. G. Patil**, Director, ICAR-CIRCOT, Mumbai 400019, INDIA; **V. G. Arude**, Scientist, same; **G. Majumdar**, Scientist, ICAR-CICR, Nagpur – 440010, INDIA

The aim of the present study is to evaluate the quality of machine picked cotton and assesses the performance of pre-cleaners specially developed for processing the machine picked cotton. A set of pre-cleaning machinery consisting of a cylinder type pre-cleaner, 3-stage stick removal machine and a saw band cleaner was used for pre-cleaning of machine picked cotton. The analysis of results suggested that the machine picked cotton contained around 19.26% total trash content among which the dry leaves were highly significant (i.e. 13.45%) compared to the large foreign matters (such as sticks and burs). The overall cleaning efficiencies of pre-cleaner, stick machine and saw band cleaner were found as 20.45%, 41.86% and 23.59%, respectively. The average percentage of trash content present in the machine picked cotton was brought down to 3.11% using saw cylinder cleaner in combination with the cylinder cleaner and stick machine. The analysis of fibre parameters suggested that the pre-cleaning operations did not make any significant difference in the fibre properties.

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1709

Land Suitability Analysis in Eastern Punjab Pakistan through Multi-Criteria Evaluation (MCE) and Analytical Hierarchy Process (AHP) In Arc GIS: **S. M. Hassan Raza**, Lecturer, Department of Space Science, University of the Punjab Lahore, PAKISTAN; **S. Amer Mahmood**, Chairman, same; **Alamgir A. Khan**, Chairman, Farm Machinery and Power, MNS University of Agriculture Multan PAKISTAN

Punjab Pakistan is famous for rice production in all over the world but economic indicators are low toward rice contribution in regional economy. Climatic and physical factors are reported to be responsible for rice yield degradation. Suitable land for rice cultivation can be mapped keeping in view these basic units. Length of rice growing season(LOS) in our study area was computed using MODIS datasets for the period April to October. Landsat 8 thermal datasets were obtained for LOS to check growth variability for each development stage of rice plant and temperature maps were generated. Multi-criteria evaluation techniques were applied to temperature and soil parameters to develop land suitability regions for rice crop. The total area under investigation was 13,657 km^2 out of which 931.61 km^2 (6.8%) was less suitable, 3,316.69 km^2 (24.2%) was moderately suitable, 6,019.63 km^2 (44%) was highly suitable and 3,395.28 km^2 (24.85%) was not suitable for rice crop cultivation. Results showed that highly suitable area is characterised by a temperature range between 21-32°C, soil pH level between 5.5 to 7.2, soil type is > 78% clay and the soil drainage is imperfectly drained. We compared land suitability map with land use land cover (LULC) map of the study area and found the following results for rice crop: 592 km^2 (5.9%) cultivations were in less suitable, 4,385 km^2 (44%) cultivations were in highly suitable, 2,210 km^2 (23.2%) cultivations were in moderately suitable and 1,674 km^2 (16.8%) cultivations were in not suitable regions. The variations in the results of suitability map and LULC classification map may be due to existence of land use features other than vegetation including urban constructions and water body etc.

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EVENT CALENDAR

◆ **AGM & Technical Conference (Joint Meeting with CIGR Section VI Bioprocesses)—FOOD, FUEL, AND FIBRE FOR A SUSTAINABLE FUTURE—**
August 6-10, Winnipeg, CANADA
www.csbe-scgab.ca/winnipeg2017

◆ **20 th FOODAGRO Africa 2017**
August 22-24, Dar-es-Salaam, TANZANIA
http://www.expogr.com/kenyafood/

◆ **SIMA ASEAN**
September 7-9, Bangkok, THAILAND
http://www.sima-asean.com/en/

◆ **13th International Congress on Mechanization & Energy in Agriculture (AGME-2017)**
September 13-15, Izmir, TURKEY
http://agme2017.org/

◆ **ASIA AGRI-TECH EXPO & FORUM 2017**
September 28-30, Taipei, TAIWAN
http://www.agritechtaiwan.com/en-us/

◆ **SIMA SIPSA—Livestock and Agri-Bushiness Show—**
October 10-13, Algiers, ALGERIA
https://www.sima-sipsa.com/

◆ **International Scientific-Technical Conference by Scientific and Practical Centre of the National Academy of Sciences of Belarus for Agriculture Mechanization (SPCNAS)**
October 18-20, Minsk, BELARUS
http://www.belagromech.by/en/

◆ **China International Agricultural Machinery Exhibition (CIAME) 2017**
October 26-28, Wuhan, CHINA
http://www.camf.com.cn/

◆ **Agritechnica 2017**
November 12-18, Hanover, GERMAY
https://www.agritechnica.com/en/

◆ **AGROCIENCIAS 2017**
November 20-24, Havana, CUBA
Organizer: Agrarian University of Havana

◆ **IX International Symposium Farm Machinery and Processes Management in Sustainable Agriculture**
November 22-24, Lublin, POLAND
http://www.kemiz.up.lublin.pl/

◆ **EIMA Agrimach India 2017**
December 7-9, New Delhi, INDIA
http://eimaagrimach.in/

◆ **5th ADDIS AGROFOOD**
December 8-11, Addis Ababa, ETHIOPIA
http://www.addis-agrofood.com/

◆ **KISAN 2017**
December 13-17, Pune, INDIA
http://pune.kisan.in/

◆ **ISAE 2018**
52nd Annual Convention of ISAE
January 8-10, 2018, Gujarat, INDIA
http://www.isae.in/

◆ **Fieragricola 2018**
January 31-February 3, Verona, ITALY
http://www.fieragricola.it/

◆ **XIX. World Congress of CIGR**
April 22-25, 2018, Kyneria, TURKEY
http://www.cigr2018.org/

◆ **GreenTech**
June 12-14, 2018, Amsterdam, NETHERLANDS
http://www.greentech.nl/amsterdam/

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

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

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Obituary

Prof. Kunihiro Tokida passed away

Professor Kunihiro Tokida, our Cooperating Editor in Japan, passed away on 6th June, 2017. It was because of Budd–Chiari syndrome. He was 60 years old. He taught at College of Bioresource Sciences, Nihon University, Japan until April this year.

He'd worked in and for African countries since 1981. He was a very thoughtful person and had profound knowledge of agricultural engineering and mechanization in Africa. His character was well shown in a motto which he wrote at the end of his e-mails: "For a better tomorrow for all."

His demise is a great loss. We wish to express our sincerest condolences to his bereaved family.

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NEWS

National Congress on "New Challenges and Advances in Sustainable Micro Irrigation"

A National Congress on "New Challenges and Advances in Sustainable Micro Irrigation" was organized at The Tamil Nadu Agricultural University (TNAU), Coimbatore during March 1-3, 2017. The three day National event was organized by the Water Technology Centre with the objectives of discussing the research outcome on micro irrigation, analyzing the challenges and to find out a solution for expanding the area under Micro Irrigation across the Country.

On 1st March, 2017, Dr. A. K. Singh, Vice-Chancellor of Rajmata Vijayaraje Scindia Krishi Vishwavidyalaya (RVSKVV), Bhopal inaugurated the Congress. Dr. K. Ramasamy, Vice-Chancellor, TNAU, Coimbatore presided over the function. In his presidential address, Dr. K. Ramasamy elucidated the important milestones in irrigation sector. He stressed the need for developing agenda at micro level for the development, conservation and utilization. Six publications and two Compact Discs on various aspects of Micro irrigation were released. Dr. V. Theivendran, Chief Engineer, Department of Agricultural Engineering, Chennai, Shri.Naresh Modi, Project Director, National Centre for Plasticulture in Agriculture and Horticulture, New Delhi, Shri.R.K.Sugoor, IFS, Joint Managing Director, Gujarat Green Revolution Company, Vadodara and Dr. S. Bhaskar, Assistant Director General of Indian Council of Agricultural Research (ICAR), New Delhi felicitated the function.

During the technical sessions, 80 research papers were presented by the Scientists and Research Scholars and 75 papers were presented through posters. Twenty eminent speakers delivered their keynote addresses.

During the inaugural function, the eminent Scientists and Farmers who have prolonged experience in micro irrigation were honored. The Lifetime Achievement Award was presented to Prof. R. K. Sivanappan, Former Dean, Agricultural Engineering College and Research Institute and Founder Director of Water Technology Centre, Coimbatore for his longest research experience in micro irrigation The other Scientists who were honored with Distinguished Scientist Awards were Dr. K. Palanisamy, Emeritus Professor, International Water Management Institute, Dr. S. Raman, Advisor, Gujarat Green Revolution Company, Vadodara, Dr. R. Sakthivadivel, Emeritus Professor, Anna University, Dr. E. J. James, Director, Water Institute, Karunya University and Dr. Megh R. Goyal, Former Professor of Agricultural and Biological Engineering, University of Puerto Rico, USA. Two farmers viz., Shri. M. Parthasarathy of Govindapuram Village in Tirupur district and Shri. P. Vetrivelan of Thondamuthur in Coimbatore district were presented with Best Micro Irrigation Farmers Award. On 2nd March, 2017, the participants were taken to a solar powered micro irrigation system installed at Chinnavedampatti for a field visit.

The Congress was concluded on 3rd March, 2017 in which the valedictory address was delivered by Dr. S. Natarajan, Vice Chancellor, Gandhigram Deemed University. Dr. B. J. Pandian, Director and Organizing Chairman narrated the progress made during the congress and Dr. S. P. Ramanathan, Professor of Agronomy and Organizing Secretary proposed the vote of thanks.

■■

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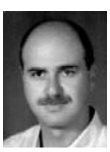
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e. have a 50 to 100-word abstract, preferably preceding the main body of the article;
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