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Edited by

YOSHISUKE KISHIDA

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This is the 159th issue since its maiden isue in the Spring of 1971

EDITORIAL

Oxfam Japan, a non-government organization reported that the gap between the rich and the poor has become wider, and now the total assets of the richest 85 people equal that of the poorest 3.5 billion.

The author started in 1971 "Agricultural Mechanization in South East Asia," the previous publication of AMA and for more than 40 years has been getting afloat "Agricultural Mechanization in Asia, Africa and Latin America." The main reason of publishing this AMA is to promote agricultural mechanization in the third world countries where the farmers have a low income. The development of communication and transportation made the world smaller mentally and the whole world becomes a big village, but the gap between the rich and the poor has grown wider now and this wide gap causes social tension and various forms of war. As a result, it is difficult to have peaceful society. To make the future world peaceful, we have to bridge the economic gap by some means. Farmers do not have high income worldwide. It is because the trade condition between agriculture and non-agriculture is not fair to the farmers. One kilo of the most expensive Japanese rice costs less than one litter of imported mineral water. Thus, farmers grow cheaper rice than bottled water.

The susceptible youth sees the agriculture unfair and tries to go to big cities. In the USA and in the third world counties, many young people try to leave the agricultural industry. Currently the world population is 7 billion and is estimated to increase to 8 billion by 2030 and this increase is happening in urban areas.

Last year, I spoke at the symposium regarding urban agriculture. Japan has more elders, and aging of the population in urban areas is becoming a problem. Also, Japan needs a system for the elders to join farming and to provide not only food, but also spiritual relief and better living space for the elderly.

Agricultural machinery is advancing in industrial countries and some emerging countries, but that in other developing countries, it is behind. To support growing population, we need to increase the productivity of the limited farmland. This can be possible by the use of proper agricultural machinery. Those who are responsible for the mechanization are the ones in the field of agricultural engineering, and they have historical and social responsibility.

Yoshisuke Kishida
Chief Editor

April, 2014

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Determination the Heat Performance for the Evaporative Cooling Pads

by

Samir B. Salman Al-Badri
Department of Agril. Machines & Equipment
College of Agriculture, University of Baghdad
IRAQ
samir_albadri75@yahoo.com

M. H. Abdul-abass
Department of Animal Production
College of Agriculture, University of Baghdad
IRAQ

Abstract

An Experiment was conducted at the Faculty of Agriculture, University of Baghdad, Abu- Ghraib, goal of research is to identify the impact of using three kinds of pads (Eucalyptus excelsior, Date palm and Plastic pads) with the daylight hours on the efficiency of evaporative cooling and amount of water evaporated through the pad. Using the fan-pad evaporative system. Pads thickness was 10 cm. Water was added into the pads by one rate of 6 L/min. The measurement had been taken during day time at 11:00 am - 5:00 pm along the process: external temperature, internal temperature, wet bulb, humidity, dew point and air speed. Calculated the efficiency of cooling pads used in the equation and finally the amount of water was calculated from the consumer through the pads during the one hour. The results showed that more reduction of temperature at 11:00 am and 5:00 pm, when using Eucalyptus excelsior pad results were 28.88 and 28.32 ºC consecutively. When Date palm pad was being used more reduction of temperature was observed at 11:00 am and 5:00 pm and the results were 28.55 and 29.31 ºC consecutively. When using Plastic pads more reduction of temperature at 11:00 am and 1:00 pm were 32.57 and 35.58 ºC consecutively. The results showed that the highest cooling efficiency at 3:00 pm, 5:00 pm and 11:00 am were 84.56, 92.97and 50.59 % respectively when used (Eucalyptus excelsior pad, Date palm pads and Plastic pads) and lowest value at 1:00 pm, 3:00 pm and 5 pm 79.26, 85.93 and 38.40 % respectively. The higher air speed at 1:00 pm, 11:00 am and 11:00 am were 1.55, 1.32 and 1.81m/s respectively when using (Eucalyptus excelsior pad, Date palm pads and Plastic pads) and lowest value at 3:00 pm 1.17, 1.17 and 1.61 m/s respectively. The lowest and higher quantity of water was Steamed during the pads liters/hour for the area 2 m^2 at 5:00 pm and 3:00 pm, when Eucalyptus excelsior pad was used results were 27.52 and 45.46 liters/hour) respectively. When Date palm pad was used for 5:00 pm and 11:00 am the lowest and higher quantity of water was Steamed were (28.86 and 37.00 liters/hour respectively. When Plastic pads was used at 5:00 pm and 1:00 pm the lowest and higher quantity of water was evaporated; results were 16.55 and 24.29 liters/hour. The study showed that changing kind of pads during different time of day affected temperature, air speed, cooling efficiency, this was due to the conditioned dry-bulb temperature that tends to vary with the outside weather temperature. As well as increasing in the amount of water vaporized during the afternoon in comparison with the morning.

Introduction

Evaporative cooling pads are used to cool down poultry house temperatures during hot weather all over the world. The efficacy of pads largely depends on how they are used and maintained. In order to get maximum cooling as well as maximum life out of your six inch evaporative cooling pad system, it is very important that the water distribution system is capable of circulating a minimum of 9 liters per minute for every meter (0.75 gallon/min/ft) of pad system length. This means, for instance, that an 18 m (60 ft) pad section should have a water distribution system capable of circulating at minimum 160 liters of water per minute over and through the pads. Before getting too concerned about total water use, one has to realize that only a small fraction of this water will actually evaporate. In fact, the recommended circulation rate is about ten times the maximum evaporation rate. So why do we need to circulate so much water? First, it is important to keep in mind that unlike the fogging pad system, with the six-inch pad system water is only applied at the very top of the pad and as a result it takes a lot of water to insure that the pads get thoroughly wetted all the way to the bottom. If insufficient water is applied, dry spots and streaking will occur. Streaking will, of course, lead to decreased cooling as some of the air entering the house moves through sections of dry pad instead of wet pad. Fan and pad systems consist of exhaust fans at one end of the barn and a pump circulating water through and over a porous pad installed at the opposite end of the barn. If all vents and doors are closed when the fans operate, air is pulled through the wetted pads and water evaporates. As each gallon of water is evaporated, 8100 BTUs of heat energy is absorbed from the air by the water during the change from liquid to vapor. Removing energy from the air lowers the temperature of the air being introduced into the barn. Evaporative cooling is a process that reduces air temperature in an airstream. As water evaporates, energy is lost from the air causing its temperature to drop. Two temperatures are important when dealing with evaporative cooling systems –dry bulb temperature and wet bulb temperature. Dry bulb temperature is the temperature that usually is air temperature. It is the temperature measured by a regular thermometer exposed to the airstream. Wet bulb temperature is the lowest temperature that can be reached by the evaporation of water only. Unlike dry bulb temperature, wet bulb temperature is an indication of the amount of moisture in the air. Wet bulb temperatures can be determined by checking with the local weather station or by investing in an aspirated psychometric, a sling psychometric, or an electronic humidity meter. Wet bulb psychomotor consists of two thermometers exposed to the same air stream.

Materials and Methods

An Experiment was conducted at the Faculty of Agriculture University of Baghdad, Abu –Ghuraib, in a poultry house without birds in summer 2007 goal of the research is to identify the impact of using three kinds of pads (Eucalyptus excelsior pad, Date palm pads and Plastic pads) during daylight hours on both the efficiency of evaporative cooling operation and amount of water evaporated through the pad, using the fan-pad evaporative system and pad thickness was 10 cm. Water was added into the pads by one rate of 6 L/min. Kestrel 3000 pocket weather meter was used in this experiment to determine temperature and wet bulb, humidity, dew point, internal temperature and air speed. Calculating the efficiency of cooling pads used in the Eq. and finally the amount of water was calculated from the consumer through the pads during the one hour.

If the efficiency of the evaporative cooling system is known, the temperature of air exiting a cooling pad can be calculated by the following **Eqn.**

$$\eta = \frac{(T_o - T_{in})}{T_o - T_w)} \times 100\ (\%)$$

ŋ = evaporative cooling efficiency (%).

T_o = dry-bulb temperature of air outside pads (ºC).

T_{in} = dry-bulb temperature of air among pads (ºC).

T_w = wet-bulb temperature of air (ºC).

Table 1 Temperate outside of barn ºC

Kind of pads	Time (hours)				Rate
	11	1	3	5	
Eucalyptus excelsior pad	37.00	40.94	43.19	43.04	40.93
Date palm	36.70	39.27	41.40	41.46	39.70
Plastic	36.00	40.00	42.06	42.69	40.18
L.S.D 5 %	0.91				0.26
Rate	36.56	40.07	42.21	42.39	40.30
L.S.D 5 %	0.30				

Table 2 Temperate inside barn among the pads ºC

Kind of pads	Time (hours)				Rate
	11	1	3	5	
Eucalyptus excelsior pad	28.32	29.60	29.44	28.88	29.60
Date palm	28.55	28.72	29.36	29.31	28.98
Plastic	32.57	35.58	36.22	37.60	35.49
L.S.D 5 %	1.10				0.25
Rate	29.81	31.3	31.67	31.93	31.17
L.S.D 5 %	0.29				

Table 3 Differ in temperatures between outside and inside barn ºC

Kind of pads	Time (hours)			
	11	1	3	5
Eucalyptus excelsior pad	8.86	11.34	13.75	14.16
Date palm	8.15	10.55	12.04	12.15
Plastic	3.43	6.48	5.84	5.09

Results and Discussion

Tables 1, 2 and **3** illustrate that more reduction of temperature for the 11:00 am and 5:00 pm when using Eucalyptus excelsior pad were 28.88 and 28.32 ºC consecutively. When using Date palm pads that more reduction of temperature resulted for the 11:00 am and 5:00 pm and were 28.55 and 29.31 ºC consecutively and when used Plastic pads that more reduction of temperature occurred for the 1:00 pm and 11:00 am and were 35.58 and 32.57 ºC consecutively. This was due to the conditioned dry-bulb temperature that tends to vary with the outside weather temperature.

Table 4 illustrates that the highest cooling efficiency at 3:00 pm, 5:00 pm and 11:00 am were 84.56, 92.97 and 50.59 % respectively when using (Eucalyptus excelsior pad, Date palm pads and Plastic pads) and lowest value at 1:00 pm, 3:00 pm and 5:00 pm 79.26, 85.93 and 38.40 % respectively as the kind of pads change the condition relative humidity increases. This was due to the greater wetted area of the pad kind and the daytime.

Table 5 illustrates the higher air speed at 1:00 pm, 11:00 am and 11:00 am were 1.55, 1.32 and 1.81 m/s respectively when used (Eucalyptus excelsior pad, Date palm pads and Plastic pads) and lowest value at 3:00 pm 1.17, 1.17 and 1.61 m/s respectively .The differences in air velocity value were due to the difficulties during wet air movement across the differences pad.

Table 6 illustrates the lowest and higher quantity of water was evaporated during the pads liters/hour for the area 2 m^2 for the 5:00 pm and 3:00 pm when used Eucalyptus excelsior pad were 27.52 and 45.46 liters/hour respectively, When used Date palm pads for 5:00 pm and 11:00 am the lowest and higher quantity of water was evaporated were (28.86 and 37.00 liters/hour) respectively and when using Plastic pads for the 5:00 pm and 1:00 pm the lowest and higher quantity of water was evaporated were (16.55 and 24.29 liters/hour) respectively this was due to the conditioned dry-bulb temperature that tends to vary with the outside weather temperature. As well as the increasing the amount of water vaporized during the afternoon than in case of the morning and different kinds of pads.

Table 4 Cooling Efficiency (%)

Kind of pads	Time (hours)				Rate
	11	1	3	5	
Eucalyptus excelsior pad	83.08	79.26	84.56	84.36	82.81
Date palm	91.27	89.90	85.93	92.97	90.01
Plastic	50.59	44.94	40.96	38.40	43.72
L.S.D 5 %	0.10				1.50
Rate	74.98	71.36	70.48	71.71	72.13
L.S.D 5 %	1.72				

Table 5 Air speed among the pads (m/s)

Kind of pads	Time (hours)				Rate
	11	1	3	5	
Eucalyptus excelsior pad	1.20	1.55	1.17	1.20	1.28
Date palm	1.32	1.20	1.17	1.17	1.21
Plastic	1.81	1.64	1.61	1.78	1.71
L.S.D 5 %	0.41				0.16
Rate	1.44	1.44	1.31	1.38	1.40
L.S.D 5 %	0.18				

Table 6 Amount of water evaporated (liters/hour)

Kind of pads	Time (hours)				Rate
	11	1	3	5	
Eucalyptus excelsior pad	43.45	41.487	45.46	27.52	39.47
Date palm	37.00	35.90	33.24	28.86	33.75
Plastic	23.27	24.29	19.15	16.55	20.81

Conclusion and Recommendation

The Date palm pads were use because it has given the higher Cooling Efficiency during day time with less Amount of water evaporated.

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Design and Development of a Hot Water Paddy Straw Pasteurizer for Mushroom Cultivation

by
Nanje Gowda N. A.
Research Scholar,
Dept. of Agricultural Engineering,
University of Agricultural Sciences,
GKVK, Bangalore-560065,
INDIA
nandi511@gmail.com

G. Senthil Kumaran
Senior Scientist,
Section of Agricultural Engineering,
Indian Institute of Horticultural Research,
Bangalore-560089,
INDIA

Abstract

Pasteurization of paddy straw is mandatory for disinfection of the substrate before spawning. This should only destroy the competitive fungi but not the beneficial microorganisms. Conventionally pasteurization of paddy straw is being done in open drums, autoclave, pressure cookers, bulk pasteurization by steaming inside tunnel, and rapid substrate steam treatment between 80 to 100 ºC for several hours. These methods are associated with several drawbacks including high water requirements, time consuming, low thermal efficiency due to heat loss, difficulty in handling of hot pasteurized straw and to drain out hot water, and higher chances of contamination due to unhygienic management. To address these drawbacks a paddy straw pasteurizer (25 kg dry straw capacity) was developed which consisted of stainless steel pasteurizing drum, temperature-time control with temperature sensor, drum tilting mechanism for loading and unloading of straw and straw compressing mechanism. From the results of performance evaluation it was found that, when paddy straw was compressed and held at maximum compressed level, 210 L of water was required for soaking and pasteurizing as compared to conventional methods (360 L). The total time needed for pasteurization was 5 h 30 min which was 2 h lesser than conventional method and thereby reducing the operation cost from 1.7 US$ to 1.2 US$ per batch pasteurization.

Nomenclature	
%	percent
mm	millimetre
A	ampere
ºC	degree centigrade
cm	centimetre
PID	proportional integral derivative
kg/m^3	kilogram per cubic metre
π	pie (22/7)
kW	kilo watt
r^2	coefficient of determination
L	litre
$	US dollar
m	metre
MT	million tonnes
m^2	square metre
C: N	carbon: nitrogen

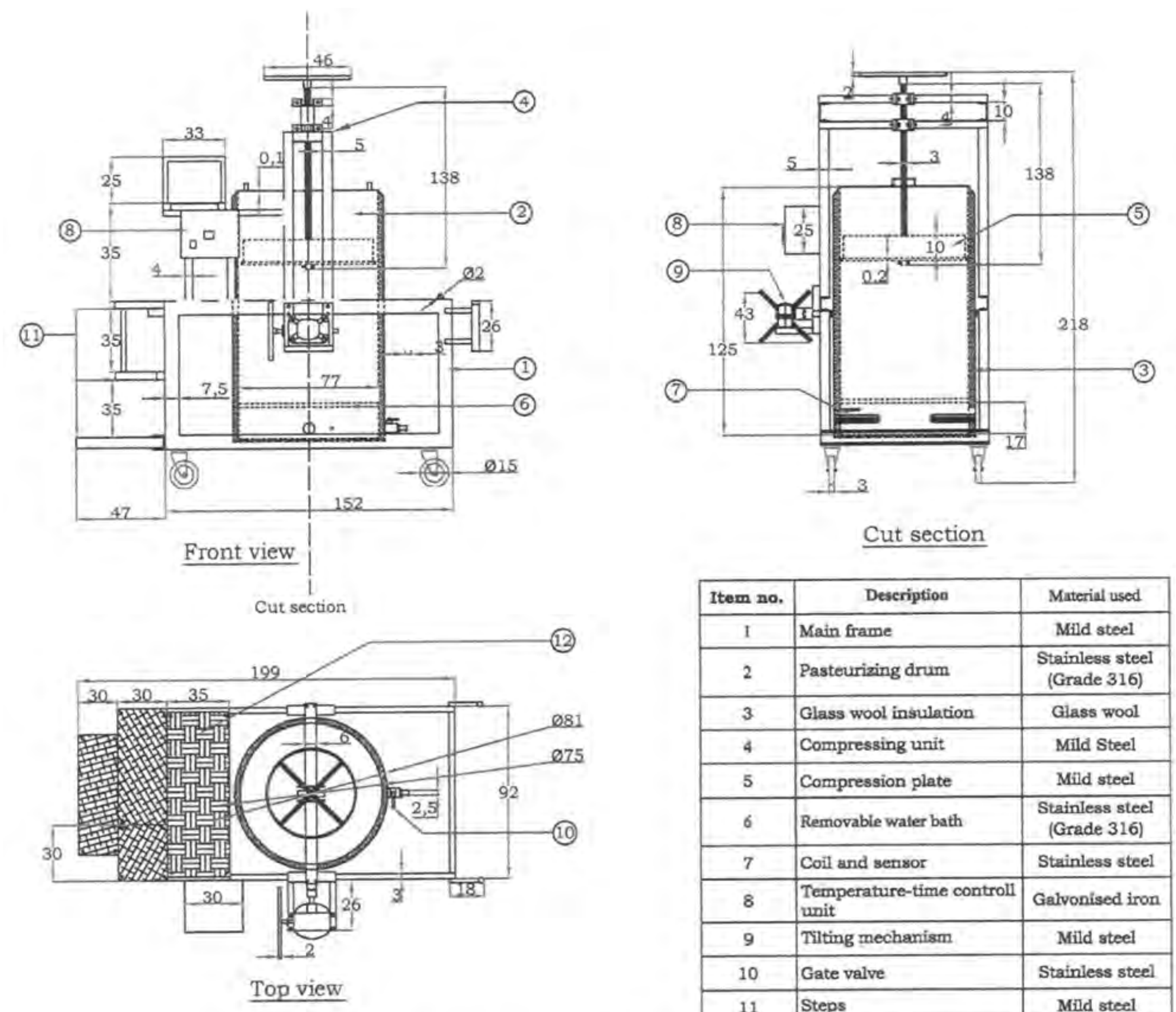
Introduction

India being the major rice producing country, around 136.5-150 MT of paddy straw is produced annually and approximately 85-95 MT of paddy straw is disposed as waste (Anonymous, 2010). Hence, paddy straw is the most commonly used substrate for growing mushrooms because of its abundance. The paddy straw mainly composed of carbohydrate components such as hemicelluloses, cellulose, and lignin (Lee, 2004b). The high amount of carbohydrate and other components such as silica and ash makes paddy straw rich in C:N ratio. Several studies have been conducted to cultivate mushroom in different organic wastes Kurtzman (1975) and Park *et al*. (1975) found that the yield on paddy straw was slightly higher than all other wastes used in studies.

Mushrooms can be cultivated on a wide range of cellulosic materials but it is necessary to avoid the damage produced by pathogens (bacteria, moulds or pests) on mushroom development and yield before substrate is spawned (Diana *et al*., 2006). Complete removal of competitive fungi Trichoderma harzianum, Coprinus cinereus and Coprinus comatus species which are most commonly found in paddy straw in very much essential. The disinfection method employed should kill only competitive fungi but not the beneficial micro-organisms. This is because the comparative organism not only competes with mycelia growth but they disturb the growth and development of competitive micro-organisms (Apahidean, 2006). Additional benefits such as faster, better and more uniform mycelium colonization assuring a better resistance against future infections are inclusive. It also makes the substrate more favourable for mushroom mycelium growth. Since sterilization kills both harmful and beneficial micro-organisms it is not ideal method for disinfection (Quimio *et al*., 1990). Subsequently, contamination problems with sterilized substrates were reported very often, since maintenance contaminant free growing conditions is arduous. Hence steam or hot water pasteurization of substrate which are traditionally followed from long back are more appropriate method for small scale mushroom growers. Pasteurized substrates are more stable and less susceptible to contamination (Chang and Miles, 2004). By considering these facts it is advised to use pasteurization rather than sterilization.

Pasteurization is an important process that loosens the tensile strength of paddy straw which is utilized by the microbial decomposers. This process also prepares the paddy straw to be easily colonized by mycelia of V. volvacea (Quimio, 1993). If pasteurization is not effective, then all the further processes will be affected right from inoculation/spawning to mushroom yield. Substrate disinfection can be done through several ways such as hot water treatment at different temperatures, hot steam or chemical methods. Amidst confusions among several mushroom growers, pasteurization seems to be the best disinfection method according to results of studies (Saritha and Meera, 2010; Kurtzman, 2010; Oseni *et al*., 2012). The common method employed pasteurization of paddy straw is

Fig. 1 Design of paddy straw pasteurizer



Item no.	Description	Material used
1	Main frame	Mild steel
2	Pasteurizing drum	Stainless steel (Grade 316)
3	Glass wool insulation	Glass wool
4	Compressing unit	Mild Steel
5	Compression plate	Mild steel
6	Removable water bath	Stainless steel (Grade 316)
7	Coil and sensor	Stainless steel
8	Temperature-time controll unit	Galvonised iron
9	Tilting mechanism	Mild steel
10	Gate valve	Stainless steel
11	Steps	Mild steel
12	Plat form	Aluminium

by soaking the paddy straw for 2 to 4 hour in open drum containing water, then boiled for 4 to 5 hour in hot water (Singh, 2006). But it was observed that the time taken for pasteurization is too long due to heat loss, low thermal efficiency in case of open drum and difficulties in handling of hot paddy straw to drain out excess water and cooling. The pasteurized straw has to be spread on mesh or floor to cool it room temperature before spawning and it takes longer time for this operation. Greater risk of contamination was observed due to the corrosive nature of pasteurizing drum itself and also due to long time exposure of pasteurized straw to the open air.

In order to address these drawbacks, a paddy straw pasteurizer was developed with a pasteurizing capacity of 25 kg dry straw per batch which is minimum requirement for any medium sized mushroom growers. The pasteurizing drum was made of stainless steel surface with glass wool insulation, temperature-time controller with temperature sensor, compressing mechanism, drum tilting mechanism for loading and unloading purposes.

Material and Methods

Description of Paddy Straw Pasteurizer

The paddy straw pasteurizer was developed and fabricated in workshop of Agricultural Engineering Section, Indian Institute of Horticultural Research (IIHR), Bangalore. For pasteurization of paddy straw KRH-1(Karnataka Rice Hybrid) variety was collected from nearest village farmer.

The following factors were considered while developing the paddy straw pasteurizer.

To pasteurize 25 kg dry straw capacity
Reducing the quantity of water and total time required for pasteurization
To obtain optimum thermal efficiency
To reduce the operation and energy cost
To get optimum mushroom yield with minimum contamination

Design Features

The paddy straw pasteurizer consists of a straw holding drum, removable base plate in water chamber with heating coils and thermocouple (PT100 type), temperature and time controller, screw compressing unit, tilting mechanism and main frame which can be studied in **Fig. 1**.

Straw Holding Drum

Any medium sized commercial mushroom farm needs to prepare at least 50 kg wet substrate every day. In order to achieve this, 25 kg dry substrate need to be prepared and pasteurized daily. The bulk density of the dry straw was found to be 43.5 kg/m^3. The diameter of the drum was assumed as 0.75 m taking into consideration of the width of corridors and doors for its convenient transportability within the mushroom farm.

Volume of the 25 kg straw = 25 kg/bulk density = 0.5747 m^3

Cross sectional area of the drum with diameter of 0.75 m was,

$= (\pi d^2/4) = 3.14 \times (0.75^2 / 4) = 0.4415\ m^2$

Height of the straw bed was,

= volume /area = 0.5747/0.4415 = 1.30 m

The water bath height of 0.15 m and free board above the straw level of 0.10 m were assumed.

The total depth of the drum = Height of straw bed + water bath + free board = 1.08 + 0.17 + 0.10 = 1.25 m

Hence, the dimension of the straw holding drum was,

Diameter = 0.75 m
Total length = 1.25 m

To reduce the heat loss through the side walls and bottom of the pasteurizer drum, 5.0 to 7.5 cm thickness of glass wool was assumed to be the best insulation material (Nandwani, 2005). To avoid heat loss at the top of drum, a stainless steel covering lid was fixed above the compression plate which closes the drum when the compression plate enters inside the drum.

Removable Base Plate in Water Chamber

The chamber depth was assumed as 0.15 m to accommodate two heating coils and sensor with sufficient free space above the coils to avoid the direct contact with the straw base. Considering the availability of the power in the rural areas, electrically operated two heating coils of 3 kW each were fitted in the water bath chamber. The coils can be operated individually or collectively depending on the power availability. It can also act as a standby if any one of the coil fails to function. A stainless steel drainage valve of 2.5 cm was also fitted at the bottom to drain-out excess water after pasteurization.

Temperature and Time Controller

Maintenance of the constant pasteurization temperature for the exact time period manually was problematic. So a suitable automatic temperature and time controller was selected and fitted. The controller unit consists of:

Contact relay (TC544) that performs functions like PID control with auto tuning, ON-OFF control and heat-cool (with auto tuning).
Electromagnetic contactor (MNX-50) capable of increasing output load supply (5 A) coming from contact relay to 50 A which is required to operate 6 kW coils.
Sensor PT100 type made out of stainless steel tube containing PT100 sensing element able to sense temperature from −10 ºC to 350 ºC and sensor wire is coated with Teflon which can resist temperature up to −10 ºC to 350 ºC.

Screw Compressing Unit

The volume of the straw bed to be compressed at different levels to study the water and energy saving. Hence, a double helix screw threaded shaft of 3 cm diameter having 6 mm pitch was mounted by providing the handle at top end and compression plate at bottom end with a fly wheel (dead weight of 20 kg) to reduce the force to be applied by the operator during compressing.

Tilting Unit

It was difficult to tilt the loaded drum (50 kilogram moist pasteurized straw and around 45 kilogram of drum weight) for unloading straw and also to handle hot straw by a single operator. A standard double worm reduction gear box with a ratio of 1:30 was attached to one side of drum shaft and frame with suitable cast iron couplings to tilt the drum for required angle for loading and unloading. This facilitates convenient tilting of drum to required angle with simple force of operator to unload the hot pasteurized straw using stainless steel hook directly on perforated tray/mesh for draining excess water and cooling it to room temperature.

Main Frame

The total weight of the pasteurizing drum was around 500 kg at fully loaded and compressed condition so to withstand this heavy weight a rigid and strong base frame was needed, so using mild steel C-channels main frame was fabricated by restricting the overall length and width of frame to 199 cm × 92 cm by considering the width of corridors and doors for convenient transportability within the mushroom farm. For operating the compressing unit four platforms having average distance of 35 cm between each other were fitted one above the other on one side of pasteurizer. For easy mobility of machine, four rubberized wheels were fixed at the bottom of the frame.

Operational Procedure

About 25 kilo gram of dry paddy straw (KRH^{-1} variety) was chopped to average length 2.5-5.0 cm and was filled by hand pressing into the pasteurizer drum. Straw bed thickness was reduced to the required level by operating compression unit. Water was then added until water appears few centimetres just above the top level of the compressed straw bed and allowed for soaking to the required time period. Power supply was switched on and the pasteurizing temperature and time was set in the time-temperature control unit. Once the temperature of water reached 80 ºC then the same temperature was maintained for 2 h. Then the gate valve was opened to drain out the water and then handle of screw press was rotated to compress the straw to maximum level so that it helps to drain excess water present in pasteurized straw. The drum was tilted to bring it to the horizontal position by rotating handle of the gear box, hot straw was then directly unloaded on a perforated tray and spread uniformly to cool it to room temperature and also to reduce moisture content around 60 percent before spawning.

Cost Economics

In order to find out the total cost of developed machine and cost incurred in pasteurization of paddy straw were calculated as follows:

Fixed Cost

a. Material cost + Fabrication cost (C) = Rs. 62000 (1171.8 $)

b. Salvage value (S) @ 10 % of total cost machine = Rs. 6200 (117.18 $)

Operational Cost

a. Annual use (U) = 1800 h per year

b. Expected life years (L) = 10 years

Fixed cost

D: Depreciation

D = (C-S) / UL = Rs. 3.1/h (0.058 $/h)

I: Interest on capital investment @ 12 % per annum on average price

$I_1 = [(C + S) / 2U)] \times 0.12$ = *Rs. 2.2/h (0.0415 $/h)*

R: Repairs/maintenance cost @ 2 %

R = (C / U) × 0.02 = Rs. 688/h (13 $/h)

Total fixed cost (D + I + R) = Rs. 6.05/h (0.114 $/h)

Variable cost

Labour cost (1 man required) = 200/day (8h) = Rs. 25/h (3.78 $)

Electricity cost

Pasteurizer coils capacity was 6 kW approximately 5 h 30 min was associated for pasteurization one batch (25 kg dry straw).

Cost per unit of electricity = Rs. 3.4 (0.064 $)

Therefore, cost of electricity for 6 units = *3.4 × 6 = Rs. 20.4/h (0.38$)*

Total variable cost = Rs. 10/h (0.189 $)

Total cost of operation (A) = Total fixed cost + Total variable cost *= Rs. 11.8/h (0.223 $)*

Statistical Analysis

MATLAB Version 3.1 (R2011a) was used to preform multi-regression analysis to determine the relationships between straw bed thickness, water quantity and time taken for pasteurization. To determine the most suitable equation, multiple regression analysis for all the parameters was used and straw bed thickness was plotted against water quantity and time of pasteurization.

Results and Discussions

The developed paddy straw pasteurizer had a capacity of 25 kg dry substrate and different view of the machine can be seen through **Figs. 2, 3 & 4**. Its performance was tested for different parameters as seen below. The tests were conducted for pasteurization of paddy straw (KRH^{-1} variety) after soaking in water overnight (Experiment 1) and also without soaking (Experiment 2) by compressing straw bed into different thickness and pasteurizing for different pasteurization temperature and time combinations. During each test 25 kg chopped dry paddy straw of 2.5-5.0 cm average length were used. In this article the performance of pasteurizer was tested for two experiments at three compressed levels with three different pasteurization temperature and time combination. Since there was no existing paddy straw pasteurizer for comparison of results with conventional method of pasteurization, the straw soaked overnight and pasteurized in same machine at 80 ºC for 2 h under loose filled condition (**Table 1**) was considered as conventional (control) method. The capacity of pasteurizer was twenty five kilogram (dry straw) for all the treatments.

The results with respect to the pasteurization after soaking overnight and without soaking, different compression levels and pasteurization temperature and time combinations, quantity of water required (l), time taken to reach maximum temperature (h) and total time taken for pasteurization (h) have been presented in **Tables 1** and **2**.

It could be seen from **Table 1** and **2** that the best performance of pasteurizer with lowest operating cost (1.23 $) was observed when paddy straw pasteurized at 80 ºC for 2 h at maximum compressed level (**Fig. 5c**) in both the experiments. However, pasteurization after soaking is a time and labour consuming process, hence this time and labour can be utilized for further processes.

Effects of straw bed thickness on water requirement and pasteurization time.

The quantity of water required for pasteurization and time taken for pasteurization as effected by compression levels (**Fig. 5a, 5b & 5c**) are given in **Table 1 & 2**. Re-

Fig. 2, 3 & 4 Different view of developed pasteurizer

Fig. 2 Front view tilted

Fig. 3 Front compressed view

Fig. 4 Inner view of drum

Fig. 5 Compression levels of paddy straw

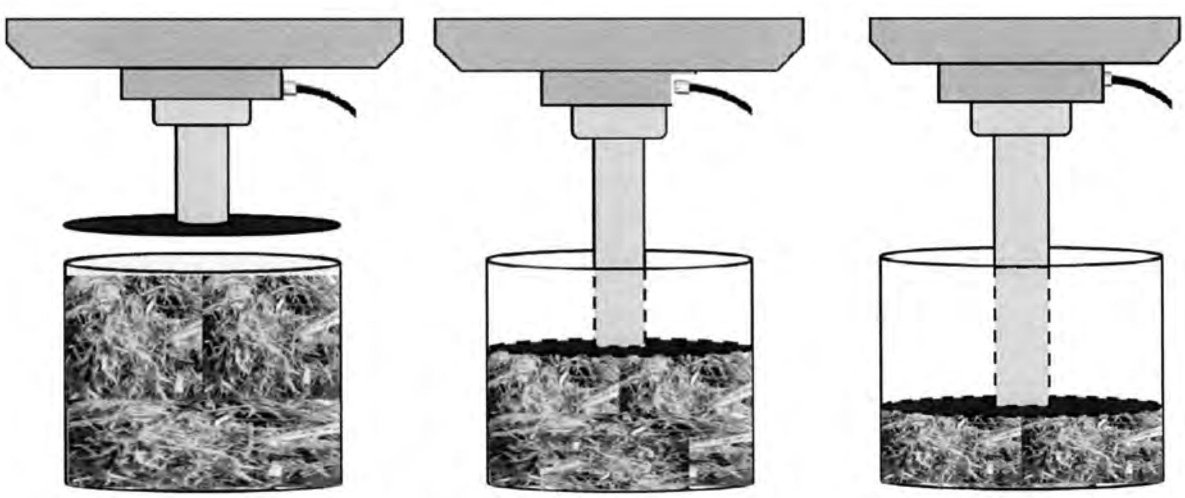


Fig. 5a Loose filled

Fig. 5b 50% compressed

Fig. 5c Maximum compressed

Table 1 Experiment 1: Pasteurization of paddy straw after soaking

Observation	Compression level								
	Loose filling			50 % compression			Maximum compression		
Quantity of straw (kg)	25	25	25	25	25	25	25	25	25
Treatments	T_1	T_2	T_3 (control)	T_1	T_2	T_3	T_1	T_2	T_3
Pasteurization temperature & duration of pasteurization	60 ºC 4 h	70 ºC 3 h	80 ºC 2 h	60 ºC 4 h	70 ºC 3 h	80 ºC 2 h	60 ºC 4 h	70 ºC 3 h	80 ºC 2 h
Initial bed thickness of straw (cm)	98	99	97	97	98	98	98	98	99
Compressed bed thickness of straw (cm)	98	99	97	47	48	48	35	34	35
Quantity of water added (L)	360	360	360	270	270	270	210	210	210
Time taken to reach pasteurization temperature (h: min)	3:00	4:15	5:30	2:15	3:30	4:45	2:30	3:00	3:30
Total pasteurization time (h: min)	7:00	7:15	7:30	6:15	6:30	6:45	6:30	6:00	5:30
Total operational cost (US $)	1.57	1.63	1.68	1.40	1.35	1.35	1.46	1.35	1.23

Note: T_1 = 60 ºC 4h, T_2 = 70 ºC 3h and T_3 = 80 ºC 2h
Control treatment = paddy straw pasteurized after soaking at 80 ºC for 2h with loose filled

sults of multi-regression analysis applied to the data (pasteurization with and without soaking) obtained from the present study showed that there was a positive linear relationship between pasteurization time (PT), straw bed thickness (X_1) and quantity of water required(X_2) (r^2 = 0.8051). From **graph 1 & 2**, it is clearly understood that the pasteurization time declined linearly with decreased straw bed thickness and water quantity (**Table 1 & 2**).

The overall relationship between pasteurization times (PT), straw bed thickness (X_1) and water quantity (X_2) for experiment1 was determined and equation1 was obtained. It was found that 80.51 % of the variation in pasteurization time was explained by straw bed thickness and water quantity.

$$PT = 263.3 + 0.3586 X_1 + 0.3623 X_2 \quad (1)$$

$r^2 = 0.8051$

Similarly, for experiment 2 the overall relationship between pasteurization time (PT), straw bed thickness (X_1) and water quantity (X_2) was determined and **Eq. 2** was obtained. It was found that 80.57 % of the variation regarding to the pasteurization time (PT) was explained by the selected independent variables, namely straw bed thickness (X_1) and water quantity (X_2).

$$PT = 266.3 + 0.3917 X_1 + 0.3445 X_2 \quad (2)$$

$r^2 = 0.8057$

The total time taken for pasteurization under loose filled (360 L of water) and 50 % compression (270 L of water) was found to increase linearly with increased temperature both in **experiments 1 & 2**. It was interesting to notice that, when straw pasteurized under maximum compression (210 L of water) the total time taken was found to decrease

FIg. 6 Pasteurization of paddy straw after soaking (Experiment 1)

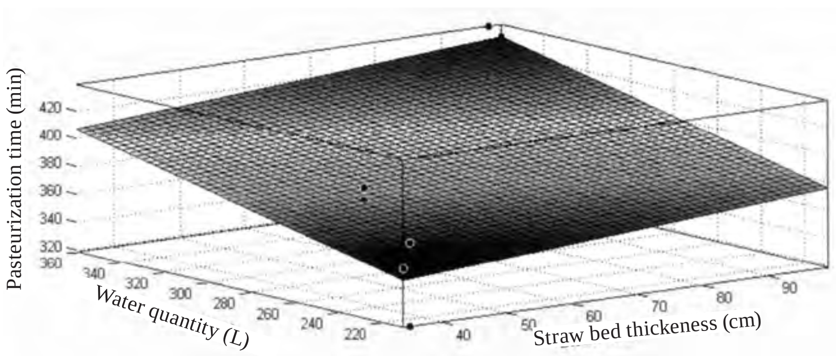


FIg. 7 Pasteurization of un-soaked paddy straw (Experiment 2)

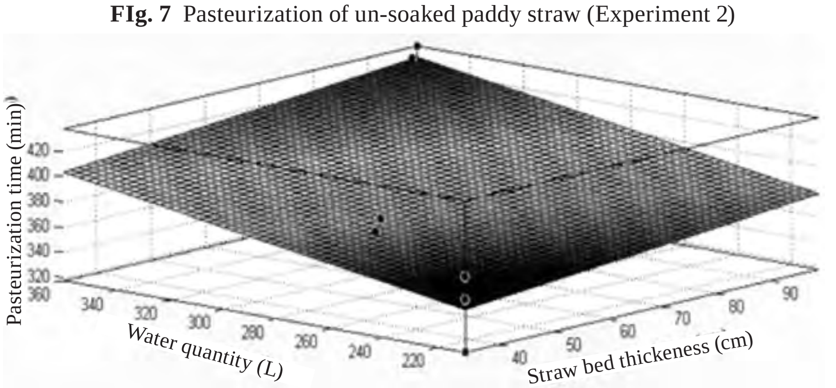


Table 2 Experiment 2: Pasteurization of un soaked paddy straw

Observation	Compression level								
	Loose filling			50 % compression			Maximum compression		
Quantity of straw (kg)	25	25	25	25	25	25	25	25	25
Treatments	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
Pasteurization temperature & duration of pasteurization	60 ºC 4 h	70 ºC 3 h	80 ºC 2 h	60 ºC 4 h	70 ºC 3 h	80 ºC 2 h	60 ºC 4 h	70 ºC 3 h	80 ºC 2 h
Initial bed thickness of straw (cm)	99	98	99	99	98	98	99	98	98
Compressed bed thickness of straw (cm)	99	98	99	48	47	48	35	34	34
Quantity of water added (L)	360	360	360	270	270	270	210	210	210
Time taken to reach pasteurization temperature (h: min)	3:00	4:15	5:30	2:15	3:30	4:45	2:30	3:00	3:30
Total pasteurization time (h: min)	7:00	7:15	7:30	6:15	6:30	6:45	6:30	6:00	5:30
Total operational cost (US $)	1.57	1.63	1.68	1.40	1.35	1.35	1.46	1.35	1.23

Note: T_1 = 60 ºC 4h, T_2 = 70 ºC 3h and T_3 = 80 ºC 2h

linearly with increased temperature. This was due to the fact that, the come up time to increase the water (360 L & 270 L under loose filled and 50 % compression respectively) temperature from ambient to 60, 70 & 80 ºC was high. While under maximum compression the come up time consumed to attain same condition was lesser, since the quantity of water was only 210 L. Hence it was determined that the pasteurization time is directly proportional to water quantity inside the drum during pasteurization. Mata and Gaitan- Hernandez (1995), Sangwan and Saini (1995), Dravininkas (1997), Pani and Das (1998), Jiskani *et al*. (1999), Bughio (2001), Balakrishna *et al*. (2001), Hussain *et al*. (2001) and Bhatti *et al*. (2007) reported different methods of boiling, pasteurization and fermentation. However the findings were almost similar to findings of present study. It was found that operating cost per batch (25 kg dry straw) of pasteurization decreased linearly from US $1.68 (conventional/control method) to US $1.23 with decrease in straw bed thickness and water quantity during pasteurization.

Conclusions

The paddy straw pasteurizer was designed and developed for easy operation, to reduce water and time requirement. Its performance was evaluated for pasteurization of paddy straw after soaking and without soaking at three temperature-time combinations and compression levels. The best performance was observed when paddy straw compressed and held at maximum compression level (**Fig. 5c**), 210 litre of water was required for pasteurization of 25 kg dry straw at 80 ºC for 2 h and the total pasteurization time taken was 5 h 30 min with a lowest operating cost of US $1.23. When the present results compared with earlier findings, the growth and production of all three variety of mushrooms obtained was identical like other workers. This is also pertinent to mention here that all the previously reported methods for pasteurization of agricultural wastes are difficult, expensive and complicated. Whereas, the developed machine in present study offers a hygienic, easiest, economical and applicable methodology. Therefore, it is recommended that, the waste material can be pasteurized for obtaining optimal yields of mushroom, without contamination and other problems faced by mushroom growers.

Acknowledgements

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Processing Non-Conventional Forages via Baling Crop Residues

by
A. F. Abdoh
Agriculture Engineer Research Institute,
EGYPT

Said Elshahat Abdallah
Associate Professor
Department of Agricultural Engineering
Faculty of Agriculture, Kafrelsheikh University
Kafr Elsheikh 33516,
EGYPT
saidelshahat@agr.kfs.edu.eg

Abstract

Selection of balers for a particular application is largely a decision based on what is available and the types of balers currently used widely. Some very recent developments in baling technology are highlighted. An investigation of the possible use of pickup baler was carried out, in order to approach zero-waste from rice and wheat straw. This research is aimed at proposing and testing an alternative method for producing non-conventional forages via chopping and compressing crop residues. There is a huge nutritional gap between the number of animal heads and the available quantity of forages, in Egypt. Therefore, the essential aim of the current study was to develop a John Deere pickup baler for chopping and compressing rice and wheat straw for processing non-conventional forages. This study was conducted by using a developed John Deere pickup baler to investigate the influence of rice and wheat straw moisture contents of (36, 30, 24 and 16 % w.b.) and (28, 25, 22 and 18 % w.b.) respectively, baler forward speeds of (1.8, 2.3, 3.5 and 4.4 km/h) and knives speeds of (18, 20, 23, and 26 m/s) on the cut lengths, efficiency of straw bales, effective field capacity, energy requirements and unit cost. The results illustrated that increasing baler forward speed from 1.8 to 4.4 km/h at knives speed of 26 m/s and rice straw moisture content of 30 %, wheat straw of 25 % w.b. tends to decrease the cut lengths of rice straw from 63 to 32 mm and from 60 to 28 mm of wheat straw, increasing the effective field capacity from 0.61 to 1.14 and from 0.655 to 1.4 fed/h respectively, decreasing energy requirements from 60.65 to 32.457 and from 56.92 to 26.42 kWh/fed respectively and decreasing unit cost from 87.06 to 46.58 and from 81.7 to 37.93 LE/fed respectively. Furthermore rice straw moisture content of 36 % w.b. and 28 % w.b. wheat straw gave the highest values of chopping length, efficiency of straw bales, energy requirements and unit cost at forward speed of 1.8 km/h and knives speed of 18 m/s.

Introduction

In Egypt, there are about two million feddans cultivated with rice each year and 2-3 million feddans cultivated with wheat each year. This produces about 5-6 million tones of rice straw and 6-7 million tones of wheat straw. Due to the lack of fodder crops and concentrates for feeding farm animals, nutritionist thought about the nutritive values of crops residues and the possibility of using it for feeding animals as it is, or after improving its nutritive values either physically, chemically or biologically. One of these crops, which give very huge amount of residues, is rice and wheat straw. However, theses residues are not safe to be used as such, and feeding considerable amounts of it in the fresh form is not advisable. Baling of rice and wheat straw may be help for solving some of the problems of animal feeding and minimize such problems of disposal and pollution at least in Kafr Elsheikh province. It may offer a significant reduction in feed cost and minimize the requirements for expensive concentrate mixture. In Egypt, the locally produced forage quantity is not sufficient for feeding the livestock population; the thing which led to a forage gap in the feeding process. There is a gap between the available quantity of green forage and the required amount of animal feed. The gap between the availability and requirement of feed is wide and the estimated shortage is 3.1 million tons of total digestible nutrients per year. The forage gap or the feed shortage has been partially narrowed to become 2.42 million tons because of using new forage resources (Agricultural Magazine, 2011). Given the importance of agricultural residues in contributing to animal feeding, especially waste rice and wheat straw. They face shortage of fodder crops and enter into combinations of animal feed and poultry manufacturers but with the use of combine harvesting machines and pickup balers, rice and wheat straw, sticks, straw, wheat stalks are long and hard on animals food it by this way or take advantage of them and the farmer collected and re-threshing again to suit the food animal and this increases the costs of the operation or the burning of such waste in the field, and especially rice straw. This is one of the most important reasons of the current in the pollution of the environment because farmers have to dispose of crop residues in order to speed evacuation of the earth and cultivation of the next crop. Therefore, the idea of this research is to benefit from such residues by means of an amendment to the pickup baler John Deere to the process frame for these residues after taken from the field, composting, in bales, and this process, the benefit can be maximized for the pickup baler a satellite to increase the number of operating hours to be used in more than one crop and reduce the costs required to process and store these bales in less space with the use time of need throughout the year. (El-Danasory and Imbabi, 1998) studied the mechanical pickup and packing of wheat straw after harvesting with combine. Results indicated that baler capacity was affected by straw mass yield and forward speed. Baler losses were decreased by decreasing forward speed and period after harvesting. They also stated that the cost of using baler to pick up baling straw was less than the half cost of manual method. (Abdallah, 2010) enhanced the thermal efficiency of the greenhouse type solar drier and modify its design to be suitable for drying crop residues. The performance of solar drier during hay making process was characterized. The developed drier could be will utilized in the domestic sector, and small and marginal farmers can also derive benefit from it. (Tarek *et al.*, 2001) developed a rice straw chopper. Their results showed that the productivity of the developed prototype was 0.95 ton/h at 2000 rpm rotor speed and cut length of (1-9 cm) reached 95.235 from the total amount of cut residue. (Abd El-Mottaleb, 2002) found that the pick up baler requires minimum values of fuel, power and energy of 7.5 L/fed., 13.8 kW and 20.3 kWh/fed of rice straw respectively. While the maximum values were noticed with the use of both round baler 14 lit/fed. 27 kWand 38 kW.h/fed of rice straw and stationary baler 28 lit/fed, 19 kW and 76 kWh/fed of rice straw. (El-Eraqi *et al.*, 2003; Imbabi, 2003 and Kamel *et al.*, 2003) indicated that the cutting length of crop residues is decreased by increasing feeding rate, cutter head drum speed, cutting knives number and decreasing the clearance between fixed and rotary knives. (Prasad and Gupta, 2005) stated that a knife approach angle of 32 degree was observed to be optimum corresponding to minimum value of energy requirements for cutting maize stalk. (Ebaid, 2006) used corn sheller for chopping cotton and corn stalks. He mentioned that the cutting length category percentage at these conditions was 63 and 45.4 % in cut length of less than 3.35 cm for corn and cotton stalk residues, respectively. It was found that the chop operation cost was estimated at 13.33 LE/ton and 20 LE/ton for cutting corn and cotton stalk residues, respectively. (Metwally *et al.*, 2006) developed and evaluate technically and economically the feeding and cutting mechanisms of chopping machine to be used for cutting the different crop residuals and pruning the fruit tree branches. They mentioned that increasing both feeding and cutting speeds tended to increase the actual capacities of chopping machine. The actual capacity of developed chopping machine increased by 28.6 % when the cutting speed increased from 0.75 to 1.88 m/s, while it decreased by 52.05 % as a result to decrease the feeding speed from 1.22 to 0.28 m/s with the cutting knife of serrated edge shape. (Arfa, 2007) modified the stationary thresher machine to become suitable for chopping and cutting farm crop residues. Oval the slops area of 4 cm^2 drum speeds of 18.33 m/s, feeding rates of 1.5 ton/h, moisture content of 14.3 % and concave clearance of 3 cm, resulting in cutting length percentage of 82.1, 85.6 and 80.1 % less than 3.5 cm for rice straw, corn stalks and cotton stalks, respectively. Energy requirement were found to be 29.9, 27.3 and 25.8 kWh/ton for rice straw, corn stalks and cotton stalks. The maximum operation cost was 25 LE/h and 17 LE/ton for rice straw.

Materials and Method

The experimental work was carried out during season 2011-2012 at Elmorabein village, Kafr Elsheikh governorate. A John Deere pickup baler was developed and some components were essentially modified for cutting and baling hay rice and wheat straw and the rest of agricultural wastes to suit the animal feed. Amendments were achieved by the following procedures:

Modifying the worm gears in nutrition from the right side by removing part of the spiral auger by 70 cm length with the addition of four beams which evenly distributed on the perimeter and are cut by knives as show in **Fig. 1**.

Adding a casual fixed number two down the upper part and a length of 70 cm mounted with knives, cut with knives, overlapping the top, through which chopping a good agricultural waste from rice and wheat straw in succession.

Adding the wave to enter the straw knives, hand pieces first before pressing the bales.

The possibility of taking into account the work of this amendment with a satellite the other pistons to maximize the benefit from this idea. The obtained windrows of rice straw was Giza-177 variety after harvesting rice by a Japanese combine harvester (2.1 m operating width) were used. John Deere pickup baler was powered by a 65 hp (48.5 kW) Nasr tractor.

Equipment:

The John Deere pickup baler was mounted on a 65 hp NASR tractor for the whole experimental work in the present study. The main components of the John Deere pickup baler are shown in Figure 1 and technical specifications are listed in **Table 1**.

Measurements:

The following items were measured during evaluating the pickup baler John Deere under the studied parameters:

Theoretical and Actual Cut Lengths

The theoretical cut length, Lth was calculated using the following equation according to Srivastava *et al*., 1995.

$$L_{th} = 60000\ V_f / \eta_c \lambda_k,\ mm \quad (1)$$

Where; V_f is the feed velocity, m/s (equivalent to the peripheral speed of feeding rolls); η_c is the cutter head rotational speed, rpm and λ_k is the number of knives on the cutter head.

After each chopping treatment, random samples (1 kg each) were taken from chopped material at the laboratory and separated to determine the actual mean of cutting length (L_{ac}). Each cutting length in the sample was weighed and calculated as a percentage in proportional to the total mass of the sample.

Effective Field Capacity

The effective field capacity (FC_E) was calculated by using the formula of Kepner *et al*., 1982.

$$FC_E = 1/T \quad (2)$$

Where; FC_E is the effective field capacity, fed/h ; T is the total time ($t + t_1 + t_2 + t_3 + \ldots$); t is the theoretical time; $t_1 + t_2 + t_3$ are the total time lost during operation; t_1 is the time lost for turning ; t_2 is the time lost for repining and t_3 is the time lost for adjusting the baler .

John Deere Pickup Baler Efficiency:

The John Deere pickup baler efficiency (E_c) was calculated by using the following formula:

$$E_c = \frac{(T.n.b - N.b.l)}{T.n.b} \times 100 \quad (3)$$

Where; T.n.b is the total number of bales per feddan and N.b.l is the number of bales looses per feddan.

Required Power:

Energy requirements were estimated by using the formula of Embaby, 1985.

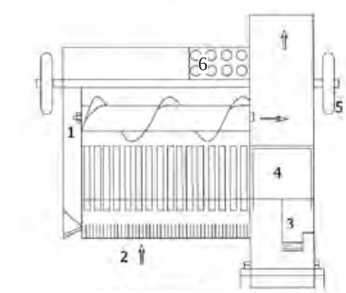
$$E_p = [F_c \times (1/3600)]\ \rho_F \times L.C.V. \times 427 \times \eta_{th} \times \eta_m \times (1/75) \times (1/1.36) \quad (4)$$

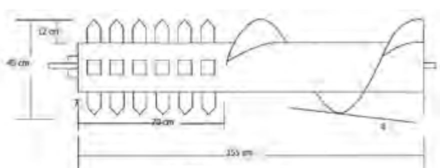
Where; E_p is the power required, kW; F_c is the fuel consumption, L/h; ρ_F is the density of fuel, 0.85kg/L; L.C.V is the lower calorific value of fuel, 10000 kcal/kg; η_{th} is the thermal efficiency of engine, 35 % for diesel engine; 427 is the thermo –mechanical equivalent, kg.m/kcal

Table 1 Technical specifications of the John Deere pickup baler (Model 338)

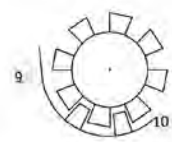
Item	Specifications
Bale size	
Height × width, cm	36 × 46
Adjustable length, cm	30.5 to 127
Pickup	
Pickup width, cm	187.9
Tooth Bars/Teeth	6bars/156 teeth
Auger	
Diameter, cm	41
Length, cm	154.9
Plunger	
Strokes/minute	80
Stroke length, cm	76.2
Baler Dimensions	
Length/long tongue, cm	576.5
Width, cm	274.3
Height, cm	170.2
Mass (empty), kg	1272
Tractor Requirements	
Speed P.T.O., rpm	540
Minimum P.T.O., hp	35

Fig. 1 Plan view of pick up baler

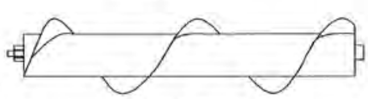




The part after amendment



side view



The part by amendment

Part no.	Part name
1	Auger
2	Pick up
3	Bale chamber
4	Ram (piston)
5	Tires
6	String
7	Knife cutting straw
8	Plate
9	Concave
10	Casual iron mounted with cutting knives

and η_m is the mechanical efficiency of engine, 80 % for diesel engine.

Energy requirement for baling

Energy requirement was calculated using the following **Eq.**:

Energy requirement (kWh/fed) = (Baling power, kW / Acual field capacity, fed/h) ....(5)

Estimation of Baling Cost:

The total hourly cost of baling rice straw and stalks of wheat using the John Deere Pickup Baler could be estimated by the following equation according to EL- Awady, 1978 as follows:

$$C = (p/h)\ [1/L + i/2 + \alpha + r] + (0.9w \times f \times u) + b \quad (6)$$

Where; C is the cost per hour of operation, L.E/h; P is the estimated price of the baler; 40000 L.E. for chopper machine and price of the tractor, 75000 L.E.; h is the estimated yearly –operating hours 1440 h (6 months ×* 30 days ×* 8 hours); L is the life expectancy of the machine, 10 years; I is the annual interest rate, 12 %; α is the annual taxes and overheads, 0.03 %; r is the annual repair and maintenance rate, 10 %; 1.2 is the correction factor for rated load ratio and lubrication; w is the engine power, 65 hp; f is the specific fuel consumption, 0.25 L/hp.h ; b is the monthly salaries, 500 L.E.; 144 is the estimated working hour's per month and u is the fuel price, 1.25 L.E/L.

Cost of Using Shredder:

C_1 = 9.44 L.E./h. and the cost of using common tractor;

C_2 = 43.67 L.E./h. and the total operating cost = $C_1 + C_2 = 9.44 + 43.67 = 53.11$ *L.E./h.*

Results and Discussion

Length of Cut:

Results of cutting length of rice and wheat straw as affected by different variables were illustrated in **Figs. 2** and **3**. It is obvious that, increasing the baler forward speed from1.8 to 4.4 km/h, at moisture content of 36 and 28 % w.b. and knives speed of 26 m/s tends to decrease the cut lengths from 7.4 to 3.6 cm and 6.7 to 3.1 cm during baling rice and wheat straw respectively. Generally, the highest value of lengths cut of 9.8 and 8.0cm was obtained at 1.8 km/h forward speed, 18m/s knives speed and moisture content of 36 and 28 % for rice and wheat straw, respectively. While the lowest value of 2.72 and 2.0 cm was obtained at 4.4 km/h forward speed, 26 m/s knives speed and moisture

Fig. 2 Effect of knives speed of choppiong lengths of rice straw at different forward speeds and moisture contents

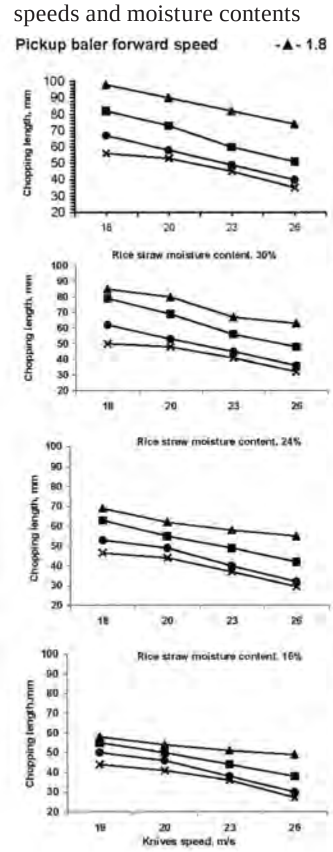


Fig. 3 Effect of knives speed of choppiong lengths of wheat straw at different forward speeds and moisture contents

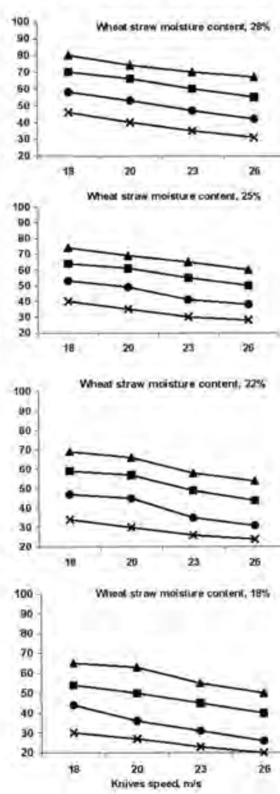


Fig. 4 Effect of knives speed on the efficiency of rice straw bales at different forward speeds and moisture contents

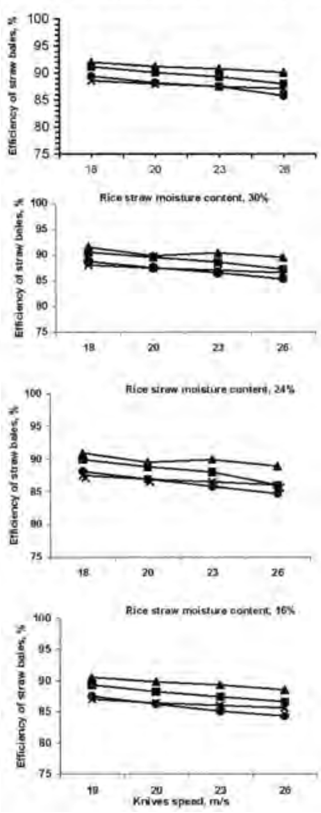
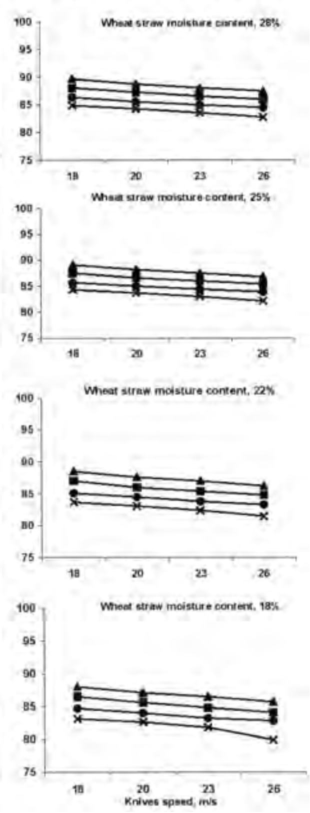


Fig. 5 Effect of knives speed on the efficiency of wheat straw at different forward speeds and moisture contents



content of 16 and 18 % w.b. for rice and wheat straw, respectively.

Efficiency of Straw Bales:

Results of straw bales efficiency for rice and wheat straw as affected by different investigated variables are illustrated in **Figs. 4** and **5**. It is obvious that, increasing the baler forward speed from 1.8 to 4.4 km/h, at moisture content of 36 and 28 % w.b. and knives speed of 26 m/s, tends to decrease the straw bales efficiency from 90.1 to 87.2 and 87.5 to 82.8 % during baling rice and wheat straw, respectively. Generally, the highest values of straw bales efficiency of 92.0 and 89.7 % were obtained at 1.8 km/h forward speed, 18 m/s knives speed and moisture content of 36 and 28 % w.b. for rice and wheat straw, respectively. While the lowest values of 85.6 and 79.9 % were obtained at 4.4 km/h forward speed, 26 m/s knives speed and moisture content of 16 and 18 % w.b. for rice and wheat straw, respectively.

Chopping Length and Effective Field Capacity:

Results of chopping length and effective field capacity of rice and wheat straw as affected by different variables are shown in **Figs. 6** and **7**. It is clear that, increasing the baler forward speed from 1.8 to 4.4 km/h, at moisture content of 16 and 18 % w.b. and knives speed of 26 m/s, tends to increase the effective field capacity from 0.63 to 1.16 and 0.66 to 1.41 fed/h during baling rice and wheat straw, respectively. Generally, the highest value of effective field capacity of 1.16 and 1.41 fed/h was obtained at 4.4 km/h forward speed, 26 m/s knives speed and moisture content of 16 and 18 % with rice and wheat straw, respectively. While the lowest value of 0.585 and 0.636 fed/h was obtained at 1.8 km/h forward speed, 18 m/s knives speed and moisture content of 36 and 28 % for rice and wheat straw, respectively.

Energy Requirements:

Results of energy requirements of rice and wheat straw as affected by different variables are depicted in **Figs. 8** and **9**. It is revealed that, increasing the baler forward speed from 1.8 to 4.4 km/h, at moisture content of 24 and 22 % w.b. and knives speed of 26 m/s, tends to decrease the energy requirements from 59.67 to 32.17 and from 56.48 to 26.33 kWh/fed, during baling rice and wheat straw, respectively. Generally, the highest values of energy

Fig. 6 Effect of knives speed on the effective field capacity at different forward speeds and moisture contents of rice straw

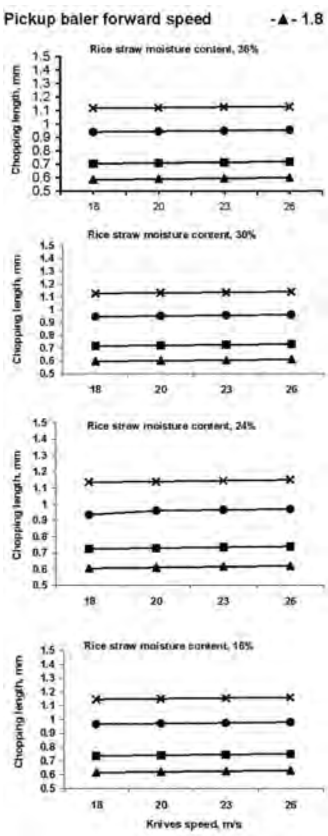


Fig. 7 Effect of knives speed on the effective field capacity at different forward speeds and moisture contents of wheat straw

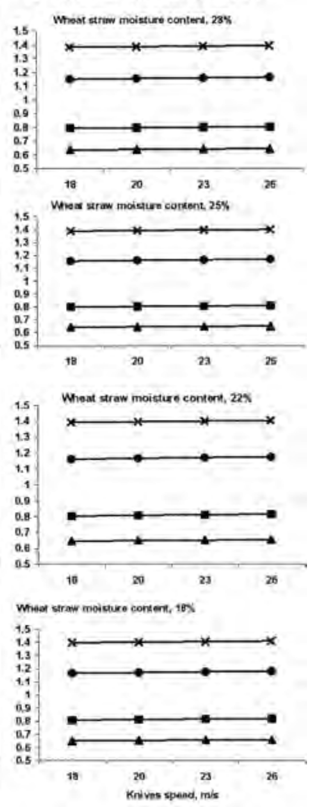


Fig. 8 Effect of knives speed on the required energy at different forward speeds and moisture contents of rice straw

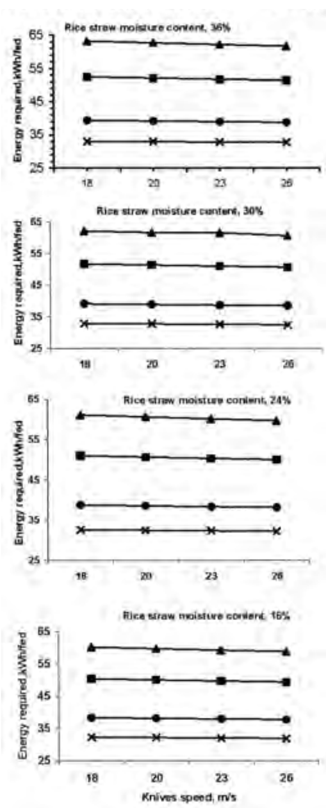
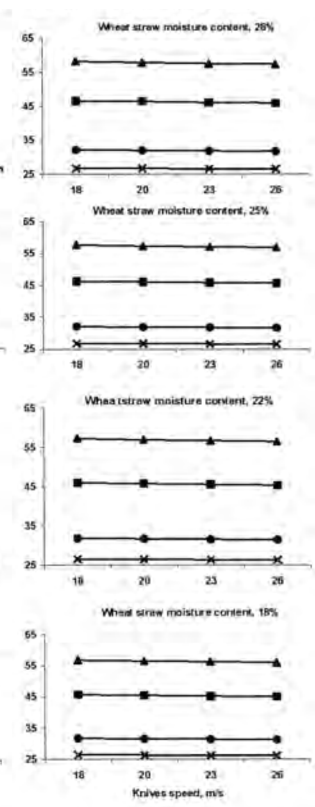


Fig. 9 Effect of knives speed on the required energy at different forward speeds and moisture contents of wheat straw



requirements of 63.24 and 58.17 kWh/fed were obtained at 1.8 km/h forward speed, 18 m/s knives speed and moisture content of 36 and 28 % for rice and wheat straw, respectively. While the lowest values of 31.89 and 26.24 kWh/fed were obtained at 4.4 km/h forward speed, 26 m/s knives speed and moisture content of 16 and 18 % for rice and wheat straw, respectively.

Unit Cost:

Results of unit cost for rice and wheat straw as affected by different variables are shown in **Figs. 10** and **11**. It is clear that, increasing the baler forward speed from 1.8 to 4.4 km/h, at moisture content of 36 and 28 % w.b. and knives speed of 26 m/s, tends to decrease the unit cost from 88.51 to 47.0 and from 82.34 to 38.07 L.E./fed during baling rice and wheat straw, respectively. Generally, the highest value of unit cost of 90.87 and 83.5 L.E./fed was obtained at 1.8 km/h forward speed, 18 m/s knives speed and moisture content of 36 and 28 % for rice and wheat straw, respectively. While the lowest value of 45.78 and 37.66 L.E./fed was obtained at 4.4 km/h forward speed, 26 m/s knives speed and moisture content of 16 and 18 % for rice and wheat straw, respectively.

Conclusions

From the abovementioned results, the following conclusions could be derived:

The amount of small cutting lengths increased as the knives and forward speed were increased. While by decreasing the percentage of straw small lengths, an increase of moisture content with rice and wheat straw was occurred, respectively.

The percentage of straw bales efficiency decreased as the knives and forward speed were increased. While by decreasing the percentage of straw bales efficiency, a decrease of moisture content with rice and wheat straw was occurred, respectively.

The effective field capacity decreased as the knives and forward speed were decreased. While by increasing the percentage of effective field capacity, a decrease of moisture content with rice and wheat straw was occurred, respectively.

Energy consumed was increased by increasing moisture content, decreasing knives and forward speeds for both rice and wheat straw.

Value of unit cost decreased as the knives and forward speed were increased. While by decreasing the value of unit cost, a decrease of moisture content with rice and wheat straw was occurred, respectively.

Fig. 10 Effect of knives speed on the total cost at different forward speeds and moisture contents of rice straw

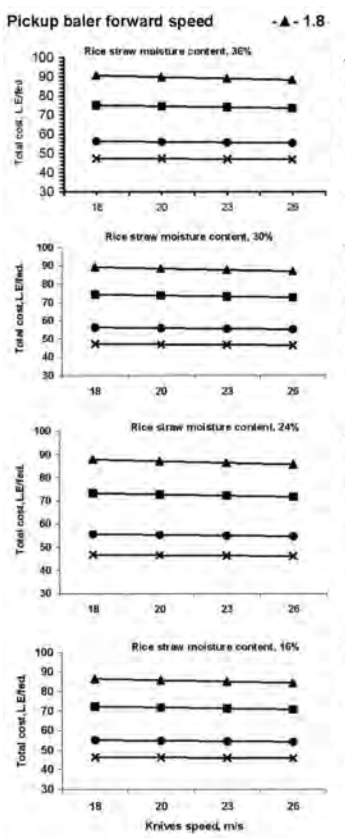
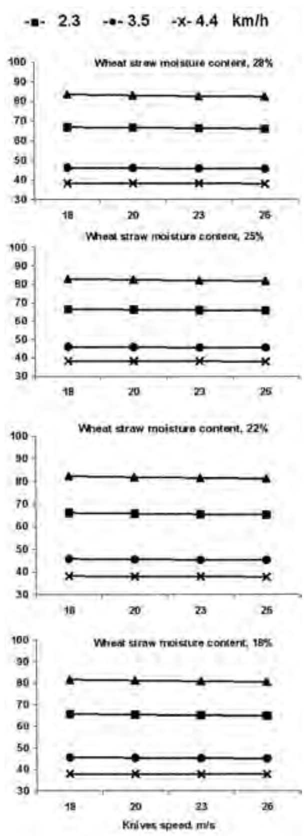


Fig. 11 Effect of knives speed on the total cost at different forward speeds and moisture contents of wheat straw



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Energy Requirement for Irrigation Pumps in Allahabad District, Uttar Pradesh (INDIA)

by
Sanjay Kumar
Senior research fallow
WZ-276 F/1A Inderuri
New Delhi-110012
INDIA
skabir_323@rediffmail.com

M. P. Chandra
Senior instructor
utter pradesh development office
INDIA

Abstract

A survey was conducted in six blocks of Allahabad district on assessment of energy requirement for irrigation pumps. Around 26 villages of six blocks have been covered. The survey revealed that the pump sets of 8 to 12 hp which was much higher than their requirement of 3 to 7 hp for irrigation. The energy requirement for each block was much higher than the actual energy required. The survey revealed that pumping system adopted by the farmers were inefficient and consume more energy at the field level. The overall results shows that awareness among the farmers about the huge energy wastage should be given that will help them in selection of proper size of irrigation pump sets.

Introduction

The heart of most irrigation systems is a pump. To make an irrigation system as efficient as possible, the pump must be selected to match the requirements of the water source, the water piping system and the irrigation equipment. Pumps used for irrigation include centrifugal, deep well turbine and submersible in this region. The energy required to pump irrigation water for crop production is measured in terms of fuel use or electric power use. Energy use depends on the amount of water pumped and on the fuel or electric power required to pump each unit of water. Before selection an irrigation pumps, a careful and complete inventory of the conditions under which the pump will operate must take place. The inventory must include:

1. The source of water (well, river, pond, etc.)
2. The required pumping flow rate
3. The total suction head
4. The total dynamic head

Ex- PG Scholars, Allahabad Agricultural Institute-Deemed University, Allahabad (U. P.)

There usually is no choice when it comes to the source of the water; it is either surface water or well, water and availability will be determined by the local geology and hydrologic conditions. However, the flow rate and total dynamic head will be determined by the type of irrigation system, the distance from the water source and the size of the piping system.

In India, 178 m ha out of 328 m ha total geological area is under cultivation. Creation of irrigation facilities are the basic need for development of agriculture and creation of employment opportunities in rural areas. Out of the 139 m ha ultimate irrigation potential, 82 m ha has been utilized for irrigation through major, medium and minor irrigation projects. Centrifugal pump sets are the most commonly used water lifting device for irrigation purpose (Taneja *et al*., 1986). There were about 8.7 million diesel pump sets and 15 million electric pump sets at the end of 2002. More then 70 percent are of centrifugal type among them. The energy used for irrigation is quite significant, approximate estimate indicate that ground water pumping requires more then 16 × 109 kWh of electricity and about 2000 million liters of diesel oil annually. After 1951, the average annual growth rate of diesel pump sets are 0.13 million whereas the electric pump sets has 0.25 million growth rate. It was estimated that 23.7 million pump sets consumed about 60.90 billion kWh of electricity and 6 billion liters of diesel. It was observed that about 90 percent of electric and diesel pump sets owned by the farmers were in the last three category of energy consumption indicating huge wastage of energy in the agricultural pump sets (Patel, 1999). It has been estimated that the overall efficiency of irrigation pump sets are 12.7 % for diesel operated and 325 for electric pump sets. Energy consumption in the existing pump sets is high due to low system efficiency. Larson and fegmeir (1978) analyzed the energy input in irrigation crops production and reported that irrigation requirement maximum energy of 73.7 percent with ground water source and 13.4 percent surface water supplied. Singh and Mittal (1985) investigated and reported the energy requirements for cultivation of major crops in Panjab. Irrigation was observed to conserve maximum energy in all crops. Singh *et al*. (1997) investigated the energy requirement for production of rice crop in different state of country. It was observed that the energy requirement 7,777 MJ/ ha for Madhya Pradesh to 103,104 MJ/ ha for Tamil Nadu the variation in energy requirements in different states could be attributed mainly to irrigation requirements and quantity of fertilizer applied. About 90 % of total energy required in rice cultivation in Tamil Nadu was through electricity used in irrigation however, in the Panjab, rice cultivation requirement 32,892 MJ/ ha of energy and nearly 50 % of it was used for irrigation and about 30 % through fertilizer and chemicals. Rice cultivation required 8,645 MJ/ha to 17,427 MJ/ha energy in West Bangal, 12,658 MJ/ha in Utter Pradesh and 8,784 to 11,330 MJ/ha in Orissa. In the same studies it was father investigated that the energy requirements for wheat crop, the total energy input ware 18,881 MJ/ha Panjab 84,496 MJ/ha in Madhya Pradesh, 14,000 MJ/ha in West Bengal and 17,482 MJ/ha in Utter Pradesh the variation in energy input was due to variation fertilizer input depending upon the availability and purchasing power of farmers. Ramachandra and Nagarathna (2001) found that water and the associated average daily energy requirement depend on the area irrigated, type of crop, sources of water, total period of irrigation and irrigation efficiency.

Materials and Methods

The survey was conducted from 26 villages fewer than six blocks of Allahabad district on assessment of energy requirement for irrigation pumps. And collected detailed information related to work from farmers of the villages like Name of farmers, Name of Block, Name of Village, size of holding, type of pump used by farmers (fuel pump/ energy pump) and pump hp etc. and calculated required parameters.

Depth of Irrigation

The depth of irrigation is calculated on the basis of available moisture holding capacity of the soil in the crop root zone in its different layers and the soil moisture extraction pattern of the crop in its root depth.

Net irrigation depth (NID) = Aw × 0.5 (Considering 50 % of moisture depletion)

Where

Aw: Available soil water

NID: Net irrigation depth (cm)

Discharge Capacity of Pump Based on Crop Requirement

The pump discharge should meet the peak demand of water for the selected cropping pattern. The rate of pumping depends on the area under different crops, the water requirement of the crops, rotation period and the duration the pump is operated each day.

Irrigation Interval

The well yield utilization pattern was estimated based on operating hours of pumps, area to irrigated, type of crop grown and soil parameter by the formula,

$q = (27.78 \times A) / (H \times I)$

Where

q: Discharge rate (lps)

A: Area irrigated (ha)

D: depth of irrigation

I: Irrigation interval (days)

H: Pump operating hours (h/day)

Water Horse Power (Whp)

Water horse power is calculated by formula given below

$WHP = (q \times H) / (75 \times 0.5)$

Where

q = Discharge rate (lps)

H = Total head (m)

System Efficiency

The system efficiency is calculated by formula given below

$\eta = (WHP \times 100) / IHP$

Where

η = System efficiency

IHP = Input horse power (hp)

Energy Index

Energy index is defined as consumption of electricity or diesel per unit of irrigation work for an ideal or desired level of electrical consumption in an efficient pumping system. Energy index of the pump sets was calculated by using the **Eqn.**

$EI = 27.78P / (q \times H)$

Where

EI = Energy index

q = Discharge rate l/s

H = Total head, m

P = Power consumption, kW

Result and Discussion

Classification of Farmer According to Land Holding

The area to be surveyed was divided according to land holding. It is shows in **Table 1** that farmers

Table 1 Category of farmers according to land holding

Serial no.	Land holding (ha)	Category	No. of farmers	percentage
1.	< 1	Marginal	7	7.4
2.	1-2	Small	17	17.89
3.	2-4	Medium	52	54.74
4.	> 4	Large	21	22.10

having < 1, 1-2, 2-4, and > 4 hectare land holding was categorized as marginal, small, medium and large farmers.

Cropping Pattern

The maximum discharge which the farmer needs was computed, knowing the cropping pattern adopted by him. It was observed that paddy was the major crop during Kharif season following wheat in the Rabi season. The other crops taken during kharif season were maize and sorghum while mustard, pea, potato and gram are taken in Rabi season.

Power Consumption of Pumps

The power consumption of the pumps for six blocks was evaluated comparing between required hp and Utilized hp for various blocks of Allahabad district. The tabular representation of results in shown in appendix **Table 2**. A clearly indicated that the variation between the average required power and average utilized power is maximum.

System Efficiency of Pump Sets

The number of farmers of each block according to system efficiency is shown in **Table 2** it was observed that for Jasra and Karchhana block had more number of farmers in the range of 30-50 %. It showed that there was more energy loss in pump sets in this area. The number of farmers having system efficiency range 50-70 % was more in Shankargarh and Chaka block. It showed that proper adoption of required hp pump sets would decrease the wastage of energy. The number of farmer having system efficiency within range of 70-90 % was more in Chaka block.

Energy Requirement for Irrigation Based on the Pumps

The energy requirement for irrigation for various blocks was also estimated based on the pumps. The calculation was done with the information i.e. discharge, WHP of pump, crop grown and available area. The energy utilization for irrigation for all blocks was higher than the actual energy used for irrigation. The tabular representation showed that the energy utilization for irrigation. It showed that the difference was lowest in Chaka block (165,508.672 MJ/ha) whereas Meja block have the highest variation in energy i.e. 415,114.995 MJ/ha. The higher energy utilization is due to lack of technical knowledge in irrigation. Farmers can reduced this excess energy by adopting the scientific approaches of water application as irrigation scheduling (crop water requirement approach, pan evaporation replenishment, soil moisture deficit etc.) and pressurized irrigation system as drip, micro-sprinkler, etc.

Energy Index of Various Blocks

Energy index of various blocks was estimated based on pumps. The calculation of energy index included discharge, pumps power and head of the established pumps. The statically data present in appendix **Table 2**, showed that the energy index was maximum in Jasra block as compared to other blocks. The energy index ranged from 0.9 to 1.5 for Chaka and Koraon block, while other blocks have EI more than 1.5. The rectification measure in agriculture pumping system can result in reduction in energy index and increase in system efficiency for other blocks.

Conclusions

It was concluded that maximum percentage i.e. about 54.74 % of medium farmer had 2-4 hectare land holding. Paddy was the major crop during Kharif season following wheat in the Rabi season. It leads to the conclusion that the pumping system adopted by the farmers was inefficient and consumed more energy at the field level. It necessiaties for the development of energy efficient pumping system as a model by combination of the standard components in irrigation pumps and their subsequent testing and evaluation. Proper extension work is needed to help the farmers in selection of pump size, suitable for their land size and cropping pattern.

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Table 2 Number of farmer for each block according to system efficiency, power and Energy

Number of farmers blocks wise	System efficiency (%)			Power (hp)		Energy (MJ/ha)		Energy index
	30-50	50-70	70-90	Required	Utilized	Required	Utilized	
Chaka	2	9	7	5.03	9.61	267,820.98	433,329.66	0.98
Jasra	11	1	3	2.2	9.36	71,909.44	348,704.78	1.69
Karchhana	9	6	0	4.16	9.43	137,632.05	439,664.01	1.57
Koraon	6	7	2	3.96	9.57	147,963.03	380,586.21	1.51
Meja	7	6	2	3.79	9.73	171,555.56	586,670.55	1.64
Shankargarh	2	12	5	3.85	9.86	174,786.30	505,992.54	1.65

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■■

Present Status of Agricultural Mechanization in Bangladesh

by

A. T. M. Ziauddin
Professor,
Department of Farm Power & Machinery,
Bangladesh Agricultural University,
Mymensingh, BANGLADESH
ziauddin_atm@yahoo.com

Tasnia Zia
Graduate Student,
Department of Statistics,
University of Dhaka, Dhaka,
BANGLADESH

Abstract

Agricultural mechanization program has been accelerated in Bangladesh in the recent years. Its level of overall development is still relatively low. Over the last two decades, the use of mechanical farm power has increased rapidly. Irrigation is now practically fully mechanised as more than one and half million diesel and electric driven pumps lift ground and surface water. Recent survey reports indicate that by 2011 about 80 % of the land was tilled by power tillers and tractors while marginal farmers have equal access to these machines through private contractor services. A good progress of mechanization has also been made in weeding, fertilizering, spraying, harvesting, threshing, drying, and transporting activities. In the past, women spent many hours processing rice with the foot operated 'dheki' but today rice hullers and mills have taken over this task. No doubt Bangladeshi farmers and rural entrepreneurs will further mechanize horizontally some of these operations to reduce costs and increase productivity through timeliness of operation. In this paper, the trends of agricultural mechanization, growth of machinery and spare parts industry, promotion of agri-machinery in Bangladesh is described. Promotion of custom hire services of field machinery and development of remote controlled low powered devices as a future strategy for reducing cost and human input energy is also discussed. Current mechanization programs and policies of the government in favour of such a growing and demanding agricultural mechanization have been carefully reviewed.

Introduction

The development of a country is related to the ability of its population to produce goods and services. Mechanization in agriculture is one of the critical inputs of production and preservation of food crops. It can increase yields through the improvement of water control, better soil preparation for planting, more efficient weed and insect control, proper crop establishment, harvesting, handling, drying, storing and processing of food, feed and fiber crops. Timeliness of all of these operations enhances yield of individual crops and maximizes the efficient use of unit area of land throughout the growing season. Agricultural mechanization should be introduced as necessary means to increase desired agricultural production at reduced cost and less human drudgery, and to generate employment or to take the place of labour absorbed by the industry or non-farm sectors. Progress of agricultural mechanization is highly favoured by the movement of people from farm to non-farm sectors. Thus, the gap of work force is gradually filled in by the machines as explained in **Fig. 1**.

Agriculture is the heart of Bangladesh economy, and rice remains its lifeblood. More than 33 million metric tons of rice was produced in 2011. It is one of the major sectors contributing 18.43 % to the GDP with a growth rate of 12.48 % as recorded in 2010-11 (BBS Sept., 2011) and employs around 44 % of the total labor force of the country. The performance of this sector has an overwhelming impact on major macroeconomic objectives like employment generation, poverty alleviation, human resources development and food security. Self-sufficiency in rice has been closely achieved, but there are clearly more gains to be made: average per hectare output of rice remains lower than India, Vietnam and China. However, the impressive gains of the last 20 years are threatened by an increasing population, food requirements and the steady loss of arable land to urban expansion and frequent disasters due to climate change. Furthermore, migration of farm labour force to more attractive non-farm jobs have already created negative pressure on productivity. Therefore, land and labour productivity in Bangladesh has to be increased. Focusing on the complementary agriculture, agricultural machinery sectors provides a powerful opportunity to do so. In doing this, Bangladesh has been pursuing complementary farm mechanization, not from the supply side, but from the demand side, organizing market pressure and developing strategic services that enable manufacturers and importers to respond appropriately.

Kulakarni (2010) reported that there is an economic advantage of mechanization. **Table 1** shows the economic advantages of mechanization as measured in percent. The increase of both land and labour productivity is mainly recognized due to timeliness of machine operation (increased cropping intensity) and their management.

In general agricultural mechanization has gained popularity among farmers for its multi-dimensional benefits such as reduction of operational cost and human drudgery, timeliness of operation, increased labour productivity and efficiency. Limited agricultural activities such as land preparation, irrigation, weeding, spraying and threshing of crops have been mechanized at least partially in Bangladesh. It needs to be extended horizontally throughout the country to harness more benefits out of it. Other labour intensive agricultural activities such as sowing seed and seedling, fertilizer applicator, drying, water saving technology & water management, storing and processing are equally demanding areas for mechanization.

Bangladesh agriculture has been facing serious challenges of scarcity of agricultural labour not only in peak working seasons but also in normal time. This is mainly for increased non-farm job opportunities having higher wage, migration of labour force to cities and low status of agricultural labourer in the society. On the other hand cultivable land is decreasing due to urbanization. Furthermore, 2 millions people are being added per year into Bangladesh population, demanding additional 3.5 lack tons of food grain each year. Fortunately, there are many opportunities to move forward with agricultural mechanization as the country has skilled manpower for research and extension, favourable policy, machine and spare parts manufacturers, traders and service providers including custom hire service of agricultural machinery.

Fig. 1 Movement of people from farm to industry and growth of agricultural mechanization

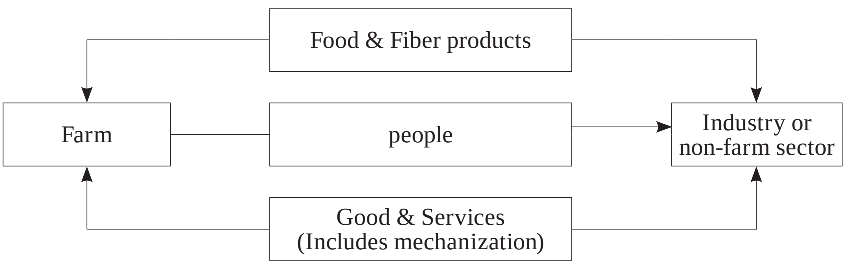
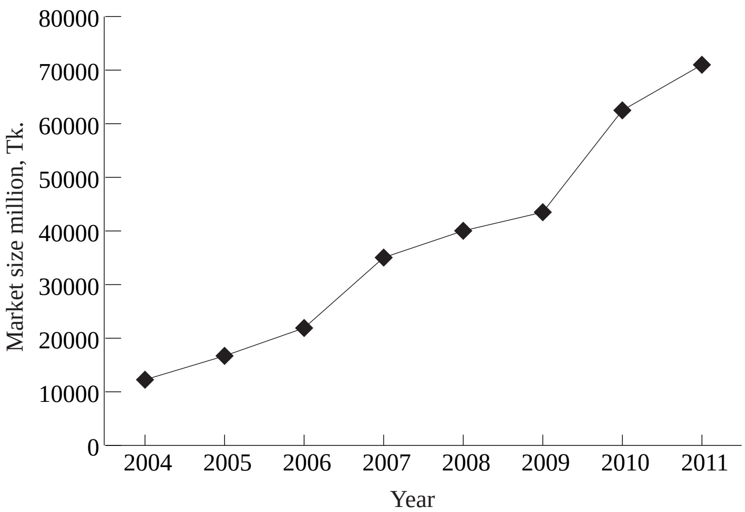


Fig. 2 Agri-machinery market trend in Bangladesh



Trends of Agricultural Mechanization

Mechanisation is gradually progressing in Bangladesh as the farmers are finding benefits in using various machines available for farming operations. Cost of tilling land with power tillers (PT) and tractors is found to be economically advantageous due to higher cost of using animal power. Moreover, Mechanization is helping to increase cropping intensity and thus significantly contributing in increase of land and labour productivity.

Since early nineties, the demand

Table 1 Economic advantages of agricultural mechanization

Item	Economic advantage, (%)
Increase in productivity	12 - 34
Saving in seeds	20
Saving in fertilizer	15 - 20
Enhancement in cropping intensity	5 - 22
Increase in gross income of the farmers	29 - 49

for agricultural machinery in the country has been increasing. In the last five years, the market grew more than three times from Tk.13 billion annually in 2004 to Tk.71 billion in 2011 (**Fig. 2**). This also encouraged the local production of agri-machinery and spares parts significantly, and decreased dependency on import (Alam *et al*., 2011). [1 Tk = US$ 0.0125]

At present there are about 550,000 PTs operating in the country (Alam *et al*., 2011). Dhaka based five large importers are the main source of supply of PTs to district wholesale and retail market. During 2004 to 2007 about 55,000 to 60,000 PTs were imported annually, with a brief period of recession in 2008-09 the import trend grow rapidly during 2010-11 and reached 130,000 units annually, worth of Tk.13,000 million (**Fig. 3**).

Today about 35,000 tractors are operating in agricultural sector, mainly in tilling and transportation purposes. In the year 2002, the number of tractors operating in the county was about 5,530 only (FAO, 2002). Since then the number of tractor import has been increasing rapidly and gradually replacing the use of power tillers in agricultural sector. Presently, on an average 6,200 tractors are being imported annually in the country (**Fig. 4**). Private companies like The Metal (Pvt) Ltd, ACI Motors Ltd., Mahindra Ltd., Corona Ltd, etc. are importing majority of the tractors and marketing through their dealers at different district towns and business centers.

At present there are about 1,425,136 shallow tube wells (STWs) and 150,613 low lift pumps (LLPs) in Bangladesh with an annual demand of 850,000 centrifugal pumps (**Table 2**). These are mostly manufactured locally. Present production volume of centrifugal pump is about 560,000. In terms of money value the growth of pumps for shallow tube wells is shown in **Fig. 5.**

All types of hand and foot sprayers are produced locally. Only knapsack sprayers are imported from China, Korea, Brazil and India. The local manufacturers collect their raw materials from Dhaka market and sell their product 30 % to district market and 70 % to other sub-districts. The annual demand of locally produced hand and foot sprayers is about 300,000 pieces, worth of Tk.156 millions. The market size of imported knapsack sprayer is about

Table 2 Growth of irrigation pumps and tube wells

Type of Pump	Early 1970s	2000	2007	2008	2010
Low Lift Pump (LLP)	24,000	71,570	107,293	138,630	150,613
Deep Tube Wells (DTW)	1,000	25,104	29,177	31,302	32,102
Shallow Tube Wells (STW)	< 1,000	757,044	1,202,728	1,304,973	1,425,136
Total	26,000	853,728	1,339,198	1,474,905	1,607,851

Source: BADC (2010)

Fig. 3 Trend of power tiller market

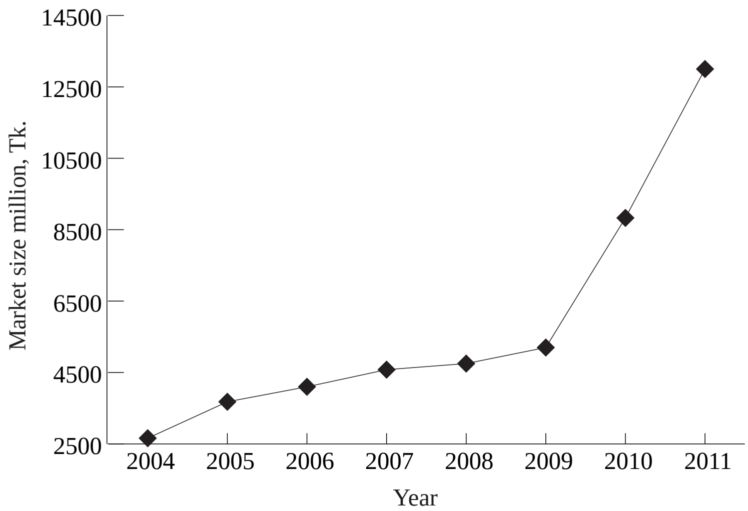
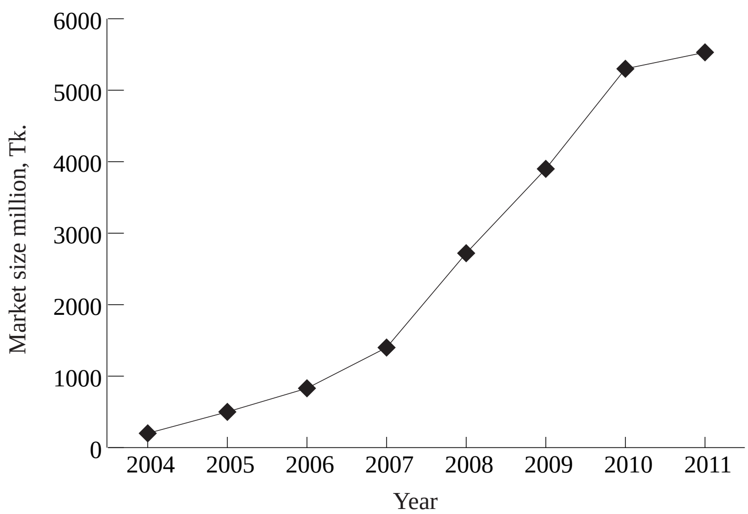


Fig. 4 Trend of tractor market



Tk.30 million per annum (Alam *et al*., 2011).

The numbers of open and closed drum threshers in the country already exceeded 150,000 and 220,000, respectively. The demand of thresher is increasing, having no competition from import. The annual demand of open and closed drum threshers is about 20,000 and 80,000 units, respectively worth of Tk.3320 millions (**Fig. 6**). A large number of reputed agricultural workshops at Bogra, Sylhet, Kishoreganj, Jessore, Netrokona, Jamalpur, Kushtia and Thakurgaon districts are manufacturing these threshers.

The demand of maize shellers is increasing rapidly with the increase in maize crop area and as well as increased land productivity. The present population of maize sheller in the country is about 18,100 with an annual demand of 6,500 units. The present market size of maize sheller is estimated about Tk.107 million per annum (**Fig. 7**).

In order to overcome scarcity of labour in harvesting and planting seasons of paddy and wheat, rice transplanter, self-propelled reaper and medium size combine harvester have high demand among the farmers. Importers like ACI motors, The Metal (Pvt) Ltd. have started importing rice transplanter and combine harvester from Korea and popularizing among the farmers. Two engineering workshops namely Janata machine tools Ltd. of Jessore and Mahbub engineering workshop of Jamalpur fabricated few units of BAU model (Hossain, 2003) self-propelled reaper for commercial purposes each costing Tk.75,000. The field capacity and efficiency of this machine is 0.21 ha/hr and 81 %, respectively with a cost saving of Tk.1475 /ha over manual harvesting of paddy. There is a huge demand of reaper in the country but the local manufacturers are facing difficulties in maintaining the precisions needed in manufacturing and thereby unable to meet the standard required for marketing of the reaper (Alam *et al*., 2011).

Other popular mechanical equipment in use on limited scale include zero till drill, bed former-cum-seeder, drum seeder, seed-cum-fertilizer applicator, manual weeders, winnower and various hand tools.

Fig. 5 Trend of pump (STW) market

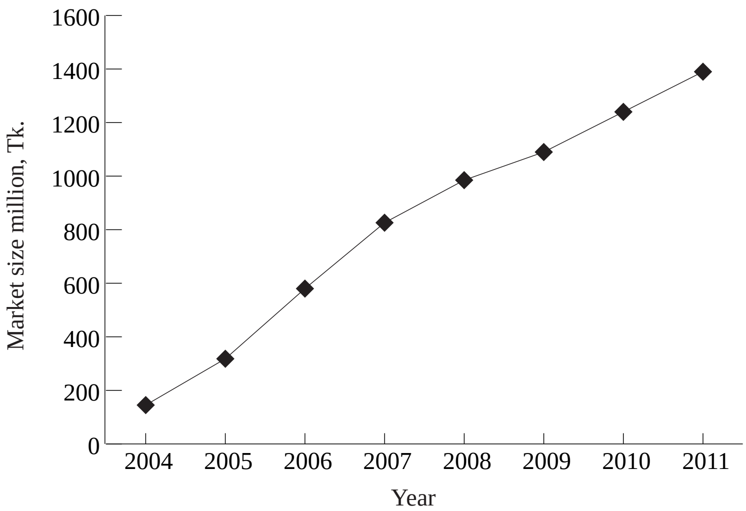


Fig. 6 Market trend of thresher, milliom Tk.

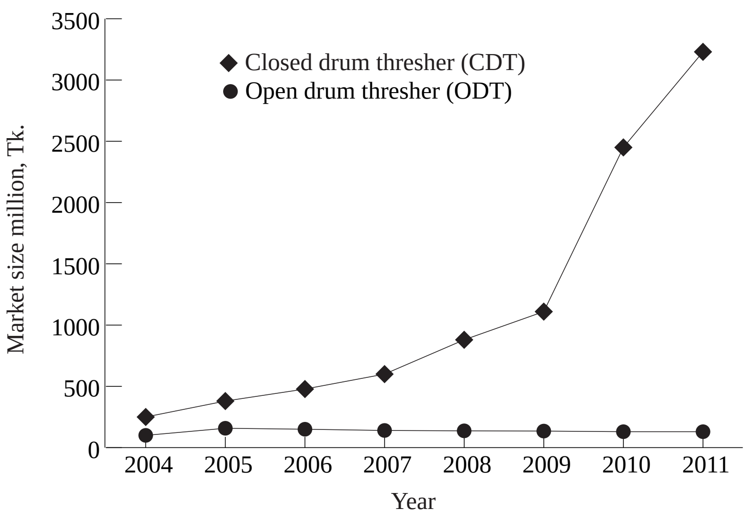


Table 3 Current statistics on farm machinery in Bangladesh

Farm Machinery	Number of units
Power tiller	about 550,000
Tractor	35,000
Low lift pump	150,613
Shallow tube well	1,425,136
Deep tube well	32,102
PT operated seeder	30
Weeder	> 200,000
Guti urea applicator	5,200
Sprayer	1,250,000
Combine harvester	about 60
Reaper	about 140
Open drum thresher	> 150,000
Closed drum thresher	> 2,20,000
Winnower	about 500
Dryer (includes rice mill dryers)	> 700
Maize sheller (power & hand)	18,100

Source: Alam *et al.* (2011)

Table 4 Percent mechanization of rice production operation in Bangladesh, 2010

Percent mechanization of field operations (Approximate)						
Land preparation	Nursery raising & transplanting	Fertilizer application	Spraying	Harvesting	Threshing	Irrigation by pump
80	05	10	90	10	68	95

Table 5 Changing pattern of land utilization (in thousand acres)

Year	Cultivable waste area	Single cropping area	Double cropping area	Triple cropping area	Net cropping area	Total cropped area
2004-05	663	7,091	10,082	2,530	19,703	34,845
2005-06	640	7,041	9,841	2,407	19,289	33,944
2006-07	634	7,027	9,822	2,417	19,266	33,922
2007-08	592	6,917	9,447	2,823	19,187	34,280
2008-09	572	6,788	9,677	3,158	19,621	35,614

Source: BBS (2011); Cultivable waste is the area suitable for cultivation but lying fellow for more than one year

Some mechanical grain dryers, sugarcane crushers, solar vegetable and fish dryers, USG applicator, potato planter, potato digger, potato graders, etc. are also in use and these are gaining popularity as better quality items are gradually coming out of local manufacturers' shops.

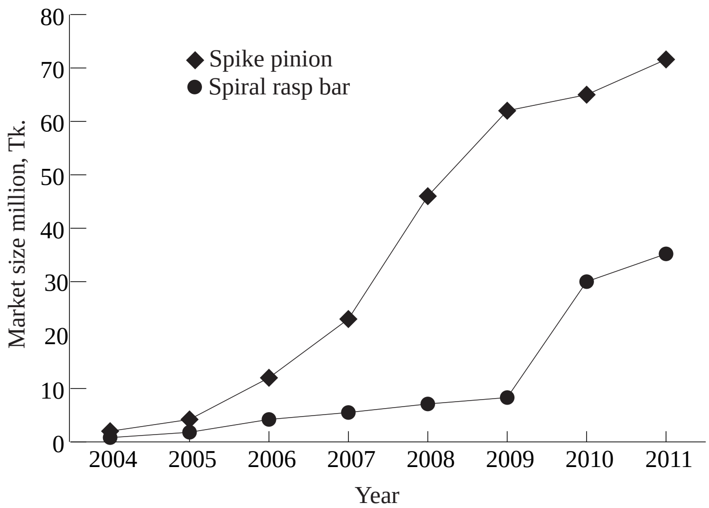
Rice milling is almost fully mechanised now. More than 30,000 small scale parboiling and milling establishments in addition to a few dozen larger automated mills are in operation. A good number of mobile rice-hulling service providers are offering services to the farmers at a cheaper rate.

In a summary the currently (2010-11) available statistics of farm machinery in Bangladesh is presented in **Table 3** below.

Major Impacts of Agricultural Mechanization

There are distinct visible changes observed during last two decades in Bangladesh in the arena of agricultural mechanization. To date operation wise mechanization of rice production in Bangladesh has been estimated and is presented in **Table 4**. The gradual penetration of mechanization resulted in shifting cultivable land from single cropping to triple cropping, mainly because of timeliness of operation. More cultivable waste areas are also being covered (**Table 5**).

Fig. 7 Trend of maize sheller market, milliom Tk



Human Energy Saving in Rice Cultivation

Rice is a labour intensive crop. About 800 to 850 man hours of labour is required for cultivating one hectare. Transplanting, weeding and harvesting operations consume most of the labour requirement in rice cultivation and hence thrust has been given for mechanizing these operations in order to reduce the labour requirement in rice cultivation. High labour demand during peak periods adversely affects timeliness of operation, thereby reducing the crop yield. Mechanization at least partially has reduced the labour requirement thus reduced the input energy of human labour (**Table 6**).

The results presented in **Table 6** imply that mechanical cultivation of land is a labour saving as well as cost reducing technology for the farmers. As a result, many farmers prefer this new mechanical technology for land preparation to the traditional Draft Animal Power (DAP) technology. Another reason for preferring this technology is that there is a scarcity of draft animal power and human labour during the peak period of the concerned crop

Table 6 Impact of PTs on cost, return and reduction of labour shortage

Season	Power option	Gross return (Tk./ha.)	Gross cost (Tk./ha.)	Net return (Tk./ha)	Reduction of labour shortage (man-days/ha.)
Boro	PT using farm	39,230	26,645	12,585	152
	DAP using farm	38,655	29,073	9,582	179
	Impact on PT	+575	−2,428	+3,003	−27
Aman	PT using farm	27,160	12,728	14,432	127
	DAP using farm	26,860	13,447	13,413	141
	Impact on PT	+300	−719	+1,019	−14

Source: Miah (2000), [1 Tk = US$ 0.0125]

Table 7 Custom hiring rate during 2010-2011

Operation	Rates*
Land tilling by power tiller using rotavator	Tk.700-800 per acre per pass
Land tilling by tractor using rotavator	Tk.1000-1200 per acre per pass
Spraying	Tk.150-200 per acre
Pumping water by LLP	Tk.1800- 2000 per acre
Threshing by pedal thresher	5-6 kg per 40 kg of threshed rice
Threshing by power thresher	5-6 kg per 40 kg of threshed rice
Transportation by PT trolley up to 5 km	Tk.200-300
Transportation by PT trolley for 5 km to 20 km	Tk.400-1200

* includes fuel, oil and operator's costs; [1 Tk = US$ 0.0125]

seasons in almost all the selected villages studied by Miah (2000). Besides, the power tiller also facilitates planting and growing of additional crops, especially in the face of quick turn around period between crops. This in fact raises aggregate output and employment in the long run.

Relief from Drudgery

Transplanting, weeding and harvesting are done in the bending posture resulting in spinal cord related health problems including back pain, muscle pain headache of the workers. Mechanization of these field operations has made sufficient relief from drudgery to the farm workers.

Reducing Cost of Cultivation

Cost of cultivation could be reduced by using alternate techniques like direct sowing of rice by drum seeder. Use of Guti urea and its placement at an appropriate depth reduces volatilization and leaching losses and thereby saving urea up to 30 percent without compromising on the yield level. Custom hiring provision of agricultural equipment has already proved to be the most significant way of reducing input cost of cultivation.

Growth of Custom Hire Services

In Bangladesh, more than 88% of the operational land holdings are either marginal (<0.5 acre) or small (0.5-2.5 acre) in size (BBS 2011). Many studies have indicated that investment capacity of majority of the farmers in these categories of land holdings is poor. These farmers can not own expensive farm power units and machinery. Farmers with small holdings utilize selected improved farm equipment through custom hiring thereby reducing their cost of cultivation. Custom-hiring facility could be of significance to both unemployed youth and the farmers.

The spread of minor irrigation equipment and power tiller have helped to develop a market for custom hire services. In the prevailing irrigation service market, the pump owners usually install their wells or pumps on their own plots to irrigate their own fields and deliver excess water to other farmers' fields under varied contractual arrangements. Some private owners of power tillers (PT) and tractor provide tillage services on contract basis. Those owning several PTs and tractors in more concentrated areas send their machine and drivers to distant but less PT and tractor concentrated areas for the season and hire out tillage services through their appointed agents. The custom hiring rate prevailing in Bangladesh during 2010-2011 is given in **Table 7**.

Case Studies on Livelihood of Rural People

Case 1: A case study of a locally developed power thresher and livelihood impact on farmer's health, income and drudgery

GRAMUS, a local NGO in Mymensingh has introduced a paddy thresher locally developed by a national GO research institution on cost sharing basis through a subproject of REFPI (2003). Men and women equally liked the technology as it has provided a good number of benefits to them such as decreased working hours and drudgery by 80 %; increased income as grain quality improved and grain losses decreased. It is interesting to note that the farmers are better off and are free from stomach ache as they are consuming quality grain today. They had complain of stomach ache when they could not thresh their harvested grain in a day or two. As a result the wet grain started deteriorating the quality. They had to consume this low quality grain as it had low market price and suffered stomach ache. This is a clear example how mechanization has improved the livelihood of rural poor.

Case 2: A case study of a day labourer who established himself as a popular agricultural service provider

Akkas Ali, a man in his mid-forties was a day labourer in Muktagachha, Mymensingh. He came away with an idea of renting out a thresher to farm households and earn money out of it. Akkas Ali obtained a power thresher from a local trader on custom hire daily basis and started offering services to farm households nearby. He was able to save money equal to 50 % price of the thresher in one season. In the following season he bought a machine on credit from the same trader. In the year 2003 he became owner of two power thresher, two pumps and a rickshaw van. He is also an employer of operators of the machines. He is a happy man earning money renting out his machines to farmers. This is an example how mechanization has improved the livelihood of rural poor. This case was identified while REFPI project personnel made a field visit in Muktagachha in 2003.

Case 3: A case study of an agricultural engineer who established himself as an agricultural machinery service provider as well as an employer

Mr. Ayub Ali, an agricultural engineer, who obtained a degree in 1990 on agricultural engineering from Bangladesh Agricultural University (BAU), Mymensingh and established himself as an agricultural machinery service provider as well as an employer based in Muktagacha, Mymensingh. In 2001 he got a job in an NGO in Comilla. After only six months in 2002, he resigned the job and started an independent business of agrilcultural machinery service providers in Muktagacha. He initially purchased a thresher and started providing service to the farmers in the area. His services earn high reputation. Subsequently with a bank loan he bought two tractors and a reaper to offer services to the rural people on demand. Mr. Ayub Ali become a successful employer too. He was the pioneer of introducing machinery rent-out service provider in Muktagacha and Mymensingh region. His business was highly profitable during 2003-2006. After 2006 his business has gradually gone down because of many service provider grew in and around Muktagacha. It is interesting to note that tractor owners along with their tractors come mainly from Jessore, Bogra and Dinajpur districts during the tillage seasons and offer services to the farmers of Muktagacha and returned back to origin in the off season. They offer services at a cheaper rate because of higher utilization of their tractors as well as they are ower-cum-mechanic.

Current Market Status of Agricultural Machinery

A recent study results on current market size of agricultural machinery, conducted by Alam *et al.* (2011) is presented in **Table 8**. It indicates that the annual estimated market size of agri-machinery and spare parts in the country is about Tk.71.16 billion with Tk.8.84 billion annual repair and maintenance service market, estimating an annual total agri-machinery market size of about Tk.80 billion of which local production market share is Tk.33.85 billion, about 42.30 % of the total market size.

Growth of Local Manufacturing Industry

During the last couple of decades, rapid growth and transformation in agriculture has triggered a significant expansion of rural non-farm activities (Hossain, 2002). The rapid growth of pump irrigation, power tillage, and threshing technologies has stimulated various manufacturing and services activities at the local level. These include manufacturing and trading of farm machinery and equipment spare parts, machinery installation, repair and maintenance services, inputs and grain trade, crop and food-processing, rural transport, rural trade and shop keeping,

Presently, Bogra is emerged as the largest agri-machinery industrial town in Bangladesh and manufacturing about 80 % of local machines and spare parts, especially irrigation pumps, threshers, maize shellers, piston, liner and numerous spare parts of small diesel engines and machines, casting of machine components etc. and counting about 80 % of the local production and Jessore is emerging next to Bogra. Other well known centers are also located in Dhaka, Chittagong, Comilla, Tangail and Kustia districts. The significant shift in the supply of spare parts in the country underlines the growth potential of the local spare parts manufacturing subsector and potential for substitution for imported spare parts. At present, there are about 70 foundries, 800 agri-machinery manufacturing industry and workshops, 1500 spare

Table 8 Annual market size of agri-machinery in 2011

Agricultural machinery	Market size/yr (Million Tk.)
Power Tiller	13,000
Tractor	5,525
Engine (STW, Thresher, Corn sheller)	21,600
Centrifugal Pump (STW & LLP)	1,400
Thresher (Open & Close drum)	3,320
Maize Sheller	107
Sprayer (local)	126
Sprayer (imported)	30
Weeder	54
Local Spare Parts	20,000
Imported spare parts	6,000
Sub-total	**71,162**
Repair & Maintenance	8,841
Total market size	**80,003**

Source: Alam *et al.* (2011), [1 Tk = US$ 0.0125] parts manufacturing industries and workshops and about 20,000 repair and maintenance workshops in the country In line with manufacturing of agri-machinery and spare parts, there are about 20,000 repair and maintenance workshops and about 500,000 mechanics are involved in repair and maintenance of engines and machines used in agricultural activities worth of about Tk.8841 million service market annually (Alam *et al*., 2011). Spare parts of power tiller, diesel engine and centrifugal pump are both imported and locally produced. This saves a huge amount of foreign currency and decrease dependency on imports. The spare parts sub-sector is employing a significant number of skilled and semi-skilled labour forces, and creates opportunities for further employment. However, this subsector is still lacking the attention of the policy planners of the country (Alam *et al*., 2011).

Beside, most common agri-machinery and spare parts production, a few items like drum seeder, push-pull weeder, potato harvester, potato grader, fish and poultry feed machine, rice grader, rice polisher, auto crusher machine, auto mixture machine, oil mill, chira/puffed rice mill, rice huller, hot mixture machine, cereal dryer machine etc. are being manufactured in the country. This sub-sector remains unexplored and there is a huge potential for growth and employment generation.

Table 9 Name and number of equipment to be offered with 25 % subsidy to farmers

Name of equipment	Total number of equipment
Power tiller	22,000
Tractor	1,000
Hand Reaper	10,000
Power Thresher	10,000
Maize sheller	1,000
Combine harvester	140
Manual weeder	5,000
Sprayer	5,000
Guti urea applicator	10,000
Total	64,140

Highlights of Recent Research Achievements

The following machines have been developed or adapted from foreign designs and tested by the R & D institutes (BRRI, BARI, BSRI, BINA, BAU, BCSIR) and produced by the private workshops/manufacturers (namely MAWTS, Alim Industries, Janata Machine, Mahabub Engg. and others). Some of them are being used in a limited scale because of low quality of fabrication. Some needs further improvement also.

- Power tiller (also imported)
- Tillage bed former-cum-seeder
- Zero till drill
- Bed former-cum-seeder
- Weeder (Manual & power)
- Treadle pumps
- Seed drill
- Guti urea applicator
- Reaper (for rice & wheat)
- Maize sheller (manual & power)
- Thresher (manual & power)
- Mechanical dryer and solar dryer
- Power tiller-operated potato planter
- Potato digger and potato grader

Promotion of Agricultural Machinery

Under the National Network, the National Research Institutes, such as BRRI, BARI, BSRI, BAU have established linkages with a good number of manufacturers, capable of fabrication and manufacturing of agricultural machinery. These private manufactures receive technical assistance i.e. prototypes, drawings and expert services from the national research institutes mentioned above. NGOs are also promoting machines by organizing landless farmers as a part of poverty reduction campaigns. CIMMYT and IRRI also supports mechanization in terms of demonstration and training in wheat and rice-wheat cropping systems.

Some project based attempts have been made by DAE, BRRI, BARI, BAU, IFDC to popularise the machines which have been tested in different locations of the country and found suitable for specific socio-economic settings of the farming system. These specialized projects have been designed to provide special efforts for wider extension, adaptation and utilization some selected items of farm machinery.

Current Mechanization Programs of the Government of Bangladesh

Ministry of Agriculture has undertaken several programs in support of agricultural mechanization such as;

Machinery subsidy program:

About Tk.1500 million project is being implemented by DAE for promotion of agricultural machines such as power tiller, tractor, combine harvester (both new and reconditioned), reaper, power thresher, maize sheller, guti urea applicator, sprayer and weeder. 25 % government subsidy on purchase price of the machines is being offered to the farmers who are free to choose any of those machines from the selected machine suppliers/manufacturers. About 237 upzilas of 25 districts are covered under this program in which a total of 64, 140 different categories of the equipment are being sold to farmers at 25 % subsidized price. The aim of the program is to increase yield, reduce cost of production, increase cropping intensity and reduce losses of already produced crops of the farmers. The name and number of machines in this subsidy program is listed in **Table 9**, ebate for Irrigation: Farmers of Barind area enjoyed 100 hours of free irrigation water input during dry period of 2009. In addition 20% rebate has been given on the electric bill for the farmers who operate their motor operated irrigation pumps.

Credit support for purchase of diesel:

During 2009-10 boro season 9,161,594 marginal, small and medium farmers have enjoyed the benefit of getting credit support for purchase of diesel for irrigation pump. About 13.8 millions farm households have already received a card under this program. Each card holder open bank account with Tk.10.00 only through which they received a total of Tk.7,220 millions credit for purchase of diesel.

Constraints Affecting Mechanization

The barriers that impede the growth and sustainability of farm mechanization industry and programs can be classified into technological constraints, socio-cultural and behavioral, financial and economic and environmental. The major constraints against the growth of agricultural mechanization and better utilization of farm machinery in Bangladesh were discussed with different stakeholders including farmers of different categories (Farouk, 2007). It is sure that farm mechanization has shown good results as of raising labour productivity, timeliness of operation and increased comfort. But a number of constraints remain present in the sector such as;

1. Majority of small cultivators are poor who are not in a position to purchase and maintain costly equipment although some of them are capable to hire equipment like LLP. PT, thresher, sprayer etc.
2. Lack of repair and replacement facilities especially in the remote rural areas
3. Very low level of attention in quality control of locally fabricated machines.
4. Inadequate service centers at village/union level and low growth of custom hiring services.
5. Lack of knowledge and skill for efficient use, proper maintenance and repair of machinery at all levels of users, artisans and traders.
6. Absence of any public sector agricultural extension activity involving farm machinery, mechanization and post harvest activities.
7. Low tariff on imported machines and high tariff on spare parts and materials need for fabrication (especially different kinds of steel).

Future Mechanization and Management

Future agriculture need is to increase the productivity and profitability of production and post-production agriculture. Diversification of agriculture, need for and introduction of new machines and the trend among the farmers to use increasingly 4-wheel tractors will vastly expand the scope for custom hiring of farm equipment. In future multi-purpose use of 4-wheel tractor with custom hiring options will be the only way to keep the operating cost of farm equipment at a reasonable level.

Table 10 shows that during 1996-2005, number of marginal and small farm holdings have increased by 73.68 % and 23.99 %, respectively. While number of medium and large farm holdings have decreased by 24.87 % and 40.6 %, respectively. Furthermore, cultivatable land is decreasing by 1 % per year due to urbanization and building of houses and other structures. This downward change of farm size clearly indicates that there would be an increased demand of farm machinery suitable for large group of marginal and small farm holdings. Farmers are left with less time for field operations. Younger generation does not want to work in the field. For these reasons development of remote controlled battery powered technologies for rice transplanter, guti urea applicator, weeder, seeder etc. will be appropriate. Very recently a project has started to develop a remote controlled guti urea applicator at Bangladesh Agricultural University (BAU), Mymensingh with the financial support of BARC. The key concept of undertaking the project of developing remote controlled devices is to reduce cost of cultivation with increased comfort of operator. If this effort be successful, the farmers will be relieved from drudgery of walking through muddy crop field thereby human input energy could significantly be reduced.

Table 10 Change in farm holdings during 1996-2005

Farm holding	No. of farms (× 1000)	
	1996	2005
Marginal farm holdings (0,05-0.49 acre)	3,356	5,829
Small farm holdings (0.5-2.49 acres)	6,067	7,523
Medium farm holdings (2.5-7.49 acres)	2,078	1,561
Large farm holdings (above 7.50 acres)	298	177

Source: BBS (2011)

Recommendations

1. Manufacturers of locally developed machinery must take responsibility of quality inspection of the machine before delivery to farmers. If necessary any appropriate policy could be formulated to protect the farmer's interest.
2. Technical know-how on machinery use, repair and maintenance should be provided to the farmers, farm workers and local artisans.
3. Inclusion of agri-machinery subsector in to the BBS database.
4. Area coverage for Irrigation mechanization should be extended from 44 % to at least 60 %.
5. One stop credit support to unemployed youth should be formulated to encourage growth of custom hire service through establishment of village/union level agrimachinery and irrigation equipment service centers.
7. Establish a high level "Agricul-

tural Mechanization Advisory Committee" with representation from all stakeholders to advise the government on agricultural mechanization issues and policies.
8. Establish a "National Centre for Agricultural Machinery (NCAM)" in any (or in combination) of the GOB institutions for development, testing and evaluation of farm machinery, with technical facilities to serve the needs of the public and private sectors.
9. Review and rationalize the current tariff rates affecting import of agricultural machines and spare parts and the raw materials needed to manufacture those locally so that local manufacturers feel encouraged to work on competitive basis.
10. Facilitate local manufacture of agricultural machines (small sized diesel/ petrol/ CNG/ LPG engines, power tillers, pumps, and reapers), accessories and spare parts by encouraging and inducing the private sector for joint venture enterprise with established world-class firms through credit/tax relief/industrial estate facilities and other effective incentives.
11. Actively participate in the programmes of the ESCAP-established "Asia Pacific Centre for Agricultural Engineering and Machinery (APCAEM)"

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LIST OF ACRONYMS

BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BCSIR	Bangladesh Council for Scientific and Industrial Research
BINA	Bangladesh Institute of Nuclear Agruculture
BRRI	Bangladesh Rice Research Institute
BSRI	Bangladesh Sugarcane Research Institute
CIMMYT	International Maize and Wheat Improvement Center
CNG	Compressed Natural Gas
DAE	Department of Agricultural Extension
DAP	Draft Animal Power
DTW	Deep Tube Well
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GO	Government Organization
GOB	Government of Bangladesh
IFDC	International Fertilizer Development Center
IRRI	International Rice Research Institute
LLP	Low Lift Pump
LPG	Liquefied Petroleum Gas
MAWTS	Mirpur Agrucultural Workshop and Training School
NCAM	National Centre for Agricultural Machinery
NGO	Non Government Organization
PT	Power Tiller
REFPI	Research and Extension in Farm Power Issues
STW	Shallow Tube Well
USG	Urea Super Granule

Selection of Suitable Furrow Opener and Furrow Closer for Vegetable Transplanter


by
B. M. Nandede

H. Raheman

H. V. Deore

Central Institute of Agricultural Engineering, Bhopal, Madhya Pradesh-462038, INDIA

Agricultural & Food Engineering Department, Indian Institute of Technology, Kharagpur, West Bengal -721302, INDIA

Abstract

Experiments were conducted in a soil bin to evaluate the commonly used furrow openers (shovel type [SL]; shoe type [SE]; runner type [RR]) and two types of furrow closers (inclined mild steel plate [PC]; double disc closer [DC]) of semi-automatic vegetable transplanters. Criteria for selection of best combination of furrow opener and furrow closer were less draft and minimum soil coverage of 100 %. It was observed that both draft and soil coverage for all furrow openers tested with both furrow closers increased with increase in operating depth and at any speed of operation. However, Soil coverage was found to be decreased as the speed of operation increased. Using Duncan Multiple Range Test, SL opener with DC was found to be the best suitable combination of furrow opener and furrow closer as it was giving required soil coverage with slightly more draft than SL opener with PC. Maximum coverage (104.4 %) was found for 20 ºC closer angle but its draft requirement was more. Hence, 15 ºC closer angle was selected as it gave required minimum soil coverage with lesser draft compared to the closer angle of 20 ºC.

Keywords: Furrow opener; Furrow closer; Draft; Soil coverage; Disc angle

Introduction

India is the second largest producer of vegetable after China. According to the National Horticulture Database, total vegetable production in India in the year 2009-2010 was 133.73 million tons grown over an area of 7.98 million hectares with a yield of 16.75 tons/ha (Anon., 2010). The estimated vegetables requirement in India by the end of 2020 will be 220 million metric tons (Pandey *et al*., 2004). Therefore, serious efforts have to be made to improve the productivity and production efficiency not only to meet the growing national demand, but also to contribute food and nutritional security and to keep India's position economically competitive in the global market (Saxena and Dhawan, 2006). Increase in crop yield and quality can be achieved by mechanized cultivation, along with other improved crop production practices (Nair, 2002; Srivastava, 1999; Clarke, 1997). Existing, commonly adopted practices for raising vegetable crops in India are either manual transplanting or mechanical transplanting. Manual transplanting is laborious, time consuming, tedious and costly. To overcome the problems in manual transplanting, mechanical transplanters were developed. Mechanical transplanters are of three types i.e. semiautomatic, automatic and robotic. Most important and common parts of a vegetable transplanter are metering devices, seedling delivery tube, furrow openers, furrow closers. Among all, furrow opener plays an important role in placement of seedlings for higher planting efficiency (Chaudhuri *et al*., 2000). The functional requirements of a furrow opener are to open a furrow to the required depth, to maintain uniformity of depth along the length of the furrow, to cause minimum disturbance to the seedbed and to prevent soil flowing back into the furrow before placement of seedlings, whereas furrow closer covers the seedlings with loose moist soil to promote and stabilize conditions conducive to rapid seedling establishment (Murray *et al*., 2006). Furrow openers and closes are a measure of the energy input and creation of better physical environment around the seedling. As these are directly related to the draft and better establishment of seedlings in the field, their assessment becomes a crucial factor in their selection. Very few studies have been done on selection of suitable furrow opener and closer and are limited to seed drills only. Various research institutions in India have developed semi-automatic and automatic transplanters listed in **Table 1** along with the type of openers and closers provided in those transplanters. For vegetable transplanter so far developed in India, no research has yet been conducted to select suitable furrow opener and closer taking into considerations the availability of power source in terms of draft requirement and better soil coverage.

Therefore, a study was undertaken at Agricultural and Food Engineering Department, IIT, Kharagpur to select the suitable furrow opener and closer for vegetable transplanter with cup type metering mechanism.

Material and Methods

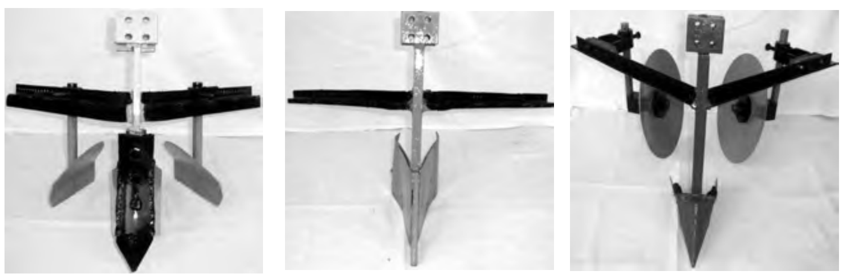
Developed Furrow Openers and Furrow Closers

From the literature reviewed, the commonly used furrow openers and furrow closers on semi-automatic vegetable transplanters were found to be shovel type (SL); shoe type (SE); runner type (RR) type and inclined mild steel plate (PC); disc type closers (DC). All these furrow openers and closers were fabricated as per standards in the workshop of Agricultural and Food Engineering Department, IIT Kharagpur and are shown in **Fig. 1**. The arrangement to attach furrow closer to the opener was made with the help of two angle iron sections attached to the shank of the opener. The holes were drilled in angle iron section at an interval of 10 mm for axial adjustment of furrow closer. Bush and solid circular rod were fabricated to ensure vertical adjustment of closers. Pre-experimental trials were conducted to fix the furrow closer distance from the shank so that there is no clogging of soil. This distance was found to be 19.5 cm. The disc angle of DC and PC were varied as 100; 150; 20 ºC and 200; 300; 40 ºC respectively, whereas tilt angle of 20 ºC was kept constant for all experiments in case of DC. Markings were made on top side of the solid circular rod to adjust the disc angle of both furrow closers.

Experimental Set-up for Laboratory Tests

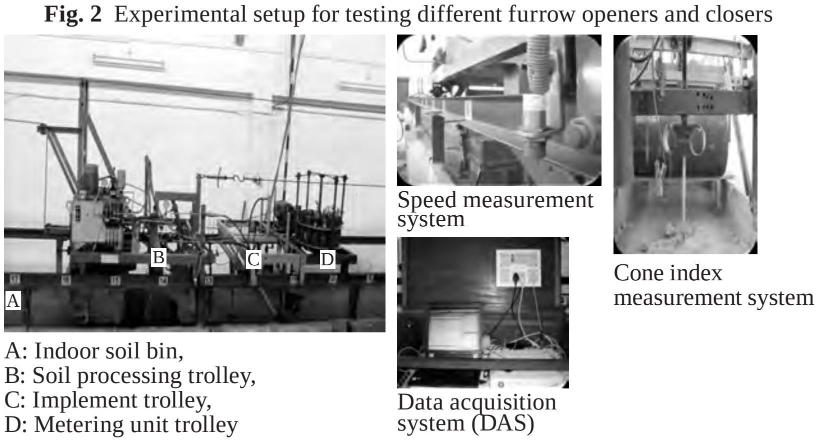
The experimental set-up for testing of different furrow opener and closer consisted of an indoor soil bin of size 15 m × 1.8 m × 0.6 m (A), a soil processing trolley (B), an implement trolley (C), a metering unit trolley (D), a speed measurement system, hydraulically operated cone index (CI) measurement system and a data acquisition system (DAS) shown in **Fig. 2**. All the three furrow openers SE, SL, RR and two furrow closers DC and PC were tested in the indoor soil bin at three operating depths (60, 70 and 80 mm) and four operating speeds (0.8, 1.2, 2.2 and 3.2 km/h) following a randomized block design with three replications. The soil in the soil bin was sandy clay loam with an average moisture content of 9.5 ± 1 % (db). A multistage cup type metering unit setup of an automatic vegetable transplanter developed at IIT Kharagpur along with furrow opener and closer was attached to the implement trolley. Dummy seedling pots made of plastic of desired size and weight were used for conducting the experiments. Draft, speed, cone index and depth were recorded in the DAS. An extended octagonal ring transducer (EORT) was used to measure draft, whereas the potentiometer was used for depth measurement. An infrared moisture meter was used to determine the moisture content of soil. Before starting the test, the soil-processing trolley comprising of ro-

Fig. 1 Developed furrow openers with closers



a) Shovel with plate closer b) Shoe c) Runner with disk closer

Fig. 2 Experimental setup for testing different furrow openers and closers



tavator and leveler was operated in the soil bin to prepare the soil bed. Cone index of about 225 ± 25 kPa and a bulk density of 1.2 ± 0.5 kg/m^3 and moisture content of 9.5 ± 1 (d.b.) were maintained in the depth range of 0-80 mm of soil bed for each test. To ensure the uniformity of compaction, five observations of cone index were taken for each seedbed. Similarly, the soil variability and uniformity of moisture were checked by collecting five samples from each seedbed along the length of the soil bin and verifying the moisture content and bulk density.

Test Procedure

Each test was carried out for a test length of 5 m in the middle span of the prepared soil bed with three replicates. After selecting a gear to obtain the desired speed and fixing the desired depth of operation for the furrow opener, the inclined plate closer was lowered to ground level and was set at required angle by matching the markings on rod and bush connecting closer. EORT was attached to the cross bar of the implement trolley and the entire setup was pulled by the soil processing trolley in the soil bin. With the help of EORT and proximity switch, the data on draft and speed of operation were continuously recorded by DAS. After the test, amount of soil covering of the seedlings was measured and expressed as percentage of soil coverage by measuring the height of pot seedling covered with soil using a scale. At the end of each test, the soil bed was disturbed and was prepared again following the same procedure to maintain the desired soil conditions for conducting other tests.

Results and Discussion

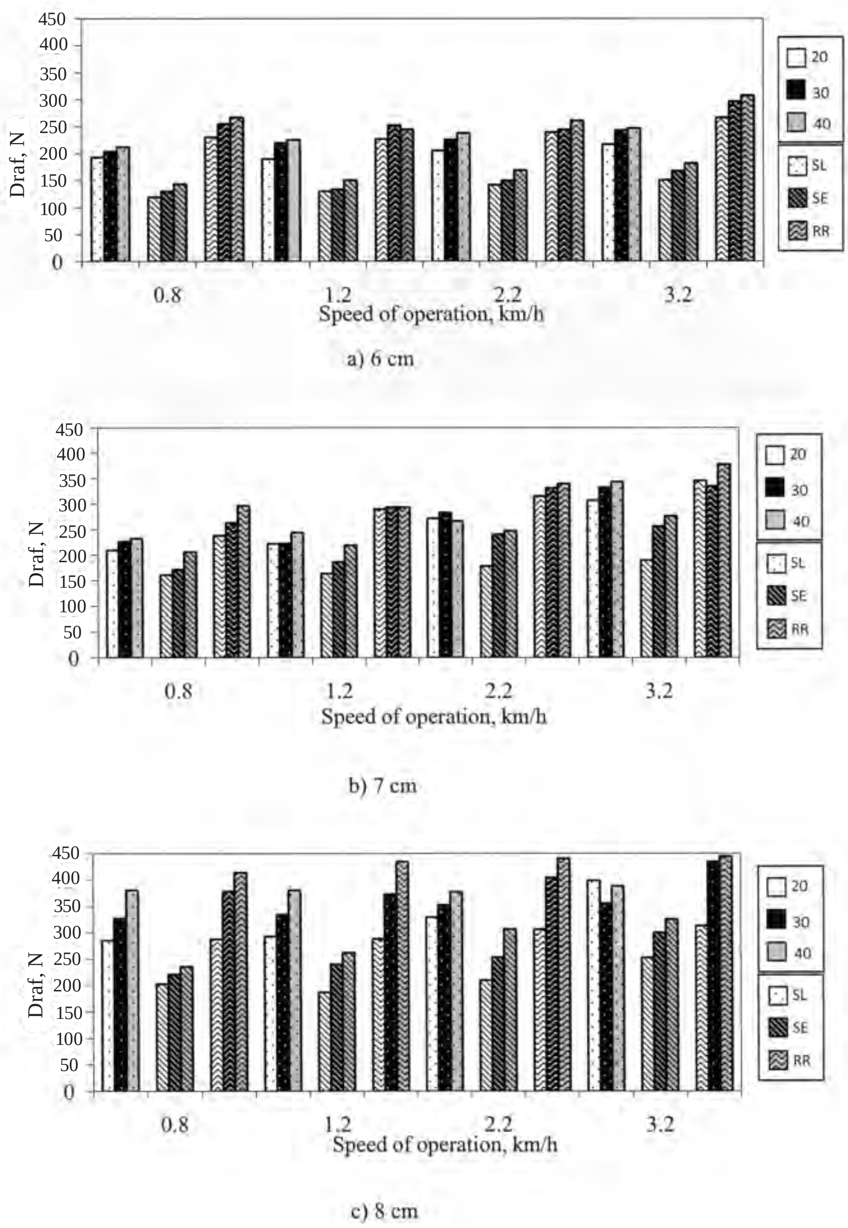
The data collected on draft and soil coverage for different furrow openers and closers by varying the operating parameters were analyzed and are presented in two groups; one comprised furrow opener (SE, SE and RR) with PC and other comprised furrow opener (SE, SE and RR) with DC.

Effect of Speed, Depth and Closer Angle on the Draft and Soil Coverage of Different Furrow Openers with PC

Types of Furrow Opener

Figs. 3a, **3b** and **3c** and **Figs. 4a**, **4b** and **4c** show the variations of draft and soil coverage of different types of furrow openers with PC at different depths, operating speeds and plate closer angles, respectively. Draft of all furrow openers was observed to be increased with increase in speed and depth of operation. Among the furrow openers tested, the draft of the RR type was found to be the highest, while the lowest draft was observed for the SE type

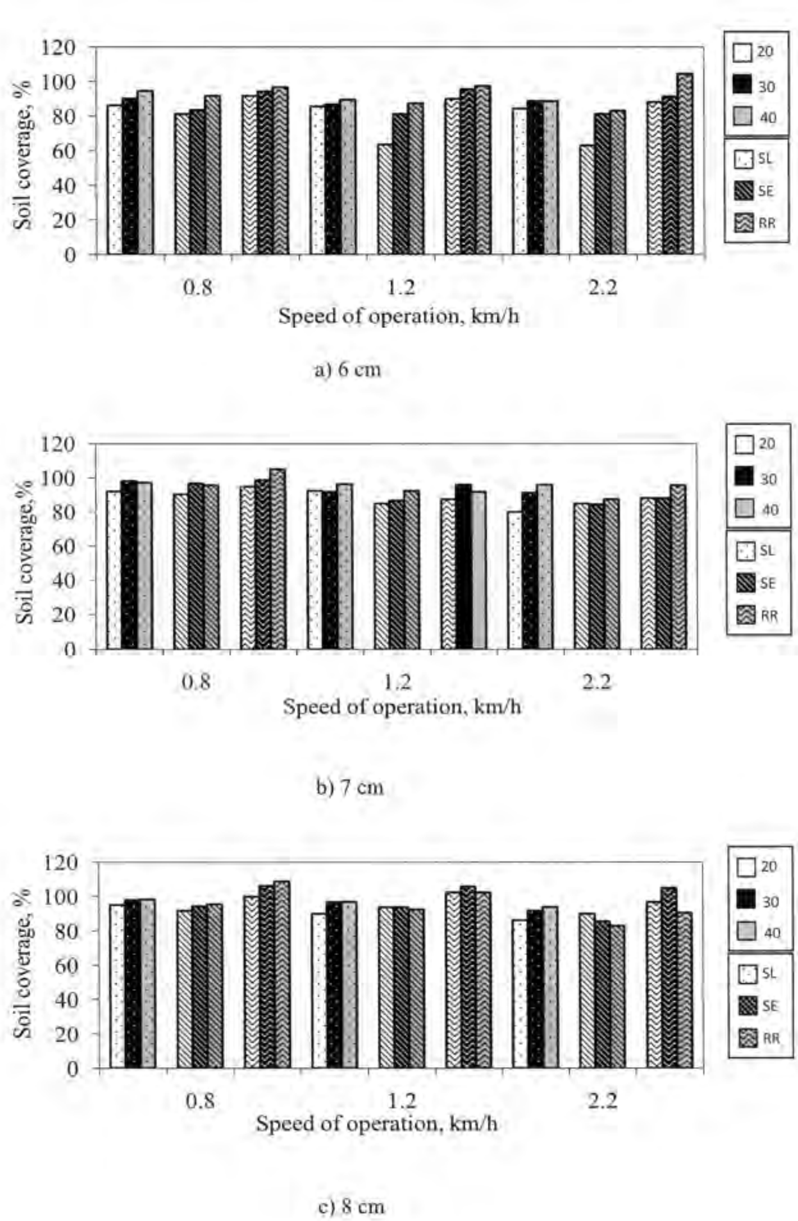
Fig. 3 Variations of draft of different types of furrow openers with plate closer at different depths, operating speeds and closer angles



for the entire ranges of speed, depth and closer angle tested. This could be due to highest and lowest cutting width obtained for the RR type and SE type furrow openers, respectively.

The soil coverage was found minimum i.e. 86 % for SE type furrow opener and it might be due to lesser width of cut obtained with SE type of furrow opener resulting in handling of lesser volume of soil as compared to other two furrow openers tested. The maximum soil coverage was obtained with RR type furrow opener i.e. 96.98 % due to maximum width of cut which allowed more volume of soil to cover the seedlings. Soil coverage with SL type furrow opener was 5.38 % lesser and 5.82 % higher than RR and SE type furrow openers, respectively.

Fig. 4 Variations of soil coverage in different types of furrow openers with plate closer at different depths, operating speeds and closer angles



Effect of Speed of Operation

Figs. 3a, **3b** and **3c** and **Figs. 4a**, **4b** and **4c**, respectively show the effect of speed of operation on the draft and soil coverage of furrow openers at different depths and plate closer angles. Draft of all furrow openers tested increased with increase in speed of operation. As the speed of operation increased from 0.8 to 3.2 km/h, the draft of SL, SE and RR type furrow openers with PC increased by 4.51 to 47.6 %, 15.3 to 48.8 % and 7.5 to 45.47 %, respectively. This was due to higher shear rate and increased soil-metal friction at higher speed of operation. However, the speed of 3.2 km/h was found unsuitable because seedlings were not vertically placed in the opened furrow due to inertia effect.

When speed of operation was increased from 0.8 to 2.2 km/h, the soil coverage was observed to be reduced by 7.32 %. Because at higher speeds, soil was thrown outside and less volume of soil was available for the plate closers to cover the seedlings.

Effect of Depth of Operation

It can be seen from **Figs. 3** and **4** that both draft requirement and soil coverage obtained for all the furrow openers tested increased with increase in depth of operation. The obvious explanation for this could be higher volume of soil handled by the tools and increased soil strength with increase in depth of operation, thus leading to higher draft and availability of more volume of soil for higher soil coverage of seedlings.

Effect of Closer Angle

It can be seen from **Figs. 3** and **4** that both draft and soil coverage of all furrow openers with PC increased with increase in angle of closer from 20 °C to 40 °C at any operating speed tested. Among the three angles tested, lowest i.e. 13 kg and highest draft values i.e. 44.4 kg as well as lowest i.e. 63.12 % and highest soil coverage i.e. 108.75 % were observed for 20 °C and 40 °C angles of PC, respectively. This was due to more volume of soil handled by the plate closers with increase in closer angle.

Effect of Operating Speed, Depth and Closer Angle on the Draft and Soil Coverage for Different Furrow Openers with DC

Types of Furrow Opener

The variations in draft and soil coverage at different depths, speeds of operation and closer angles of different furrow openers are shown in **Figs. 5a**, **5b** and **5c** and **Figs. 6a**, **6b** and **6c**, respectively. The drafts of all furrow openers increased with increase in speed and depth of operation. Among the furrow openers tested, the draft of the RR type was found to be the highest, while the lowest draft was observed for the SE type furrow opener for the entire range of speed, depth and closer angle tested. This was due to highest width of cut for any depth of operation obtained with RR type furrow opener. The lowest width of cut was observed for the SE type furrow opener.

The soil coverage was found lowest, i.e. 94.5 % for SE opener because it was creating less soil disturbance; hence less volume of soil was available to cover the seedlings. However, highest soil coverage was observed for RR type opener due to maximum width of cut which made more volume of soil available to cover the seedlings.

Effect of Speed of Operation

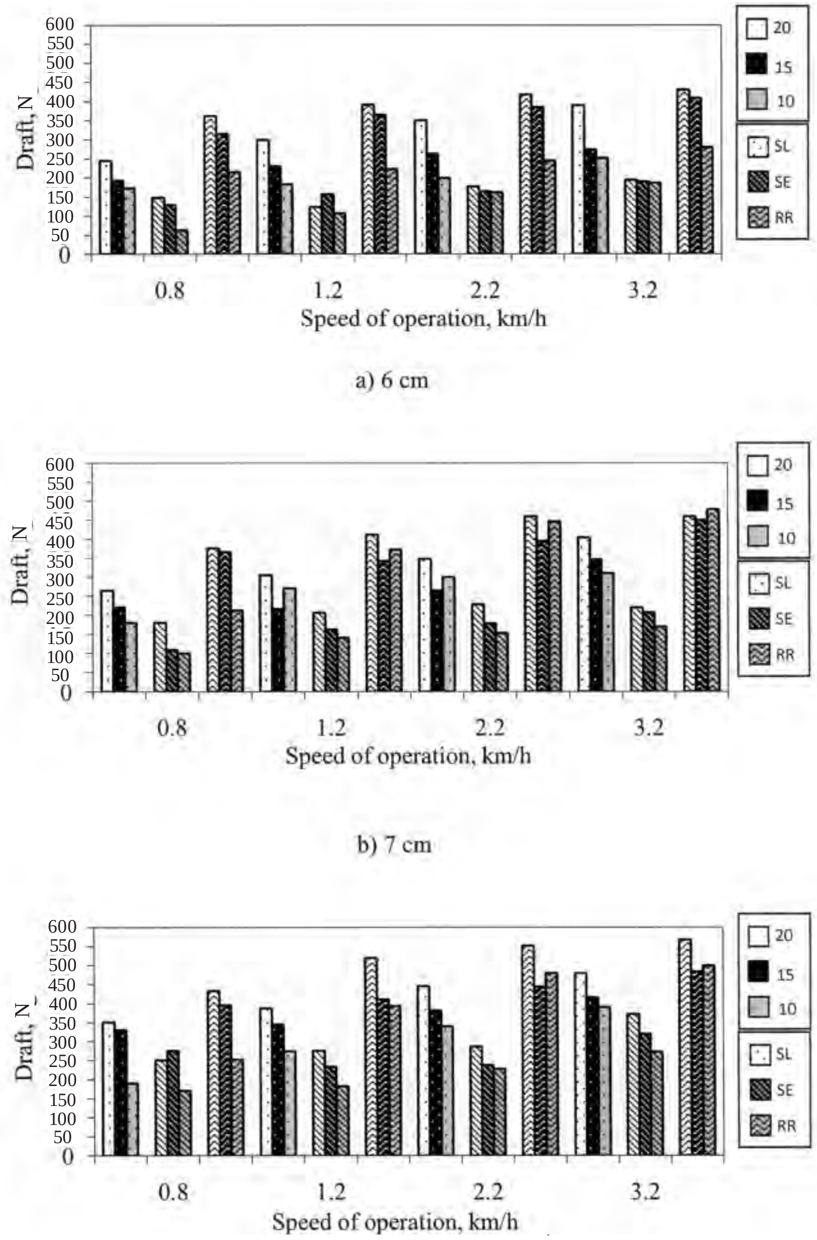
The draft of all furrow openers with DC increased with increase in speed of operation as shown in **Figs. 5a**, **5b** and **5c**. The draft was found to increase from 25.73 to 104 %, 15.83 to 90.43 % and 7.46 to 125 %, when the speed of operation was increased from 0.8 to 3.2 km/h. The possible reason behind this might be rapid acceleration of soil with increased normal load on soil engaging surfaces, thereby increasing the frictional resistance and also because of kinetic energy imparted to the soil. Higher speed resulted in higher shear rate thus leading to higher draft. However, at 3.2 km/h speed, the seedlings were falling in the furrow with an angle of inclination more than 50 °C due to inertia effect. Hence, this speed was found unsuitable for vegetable transplanter with pot seedlings.

Soil coverage decreased by 9.44 % with increase in speed of operation from 0.8 to 2.2 km/h. Because at higher speeds, soil was thrown outside so less volume of soil was available for DC to cover the seedling (**Figs. 6a**, **6b** and **6c**).

Effect of Depth of Operation

It can be seen from **Figs. 5** and **6** that both draft requirement and soil coverage obtained for all furrow openers with DC increased with increase in depth of operation. The obvious explanation for this could be higher volume of soil handled by

Fig. 5 Variations of soil coverage in different types of furrow openers with disc closer at different depths, operating speeds and closer angles

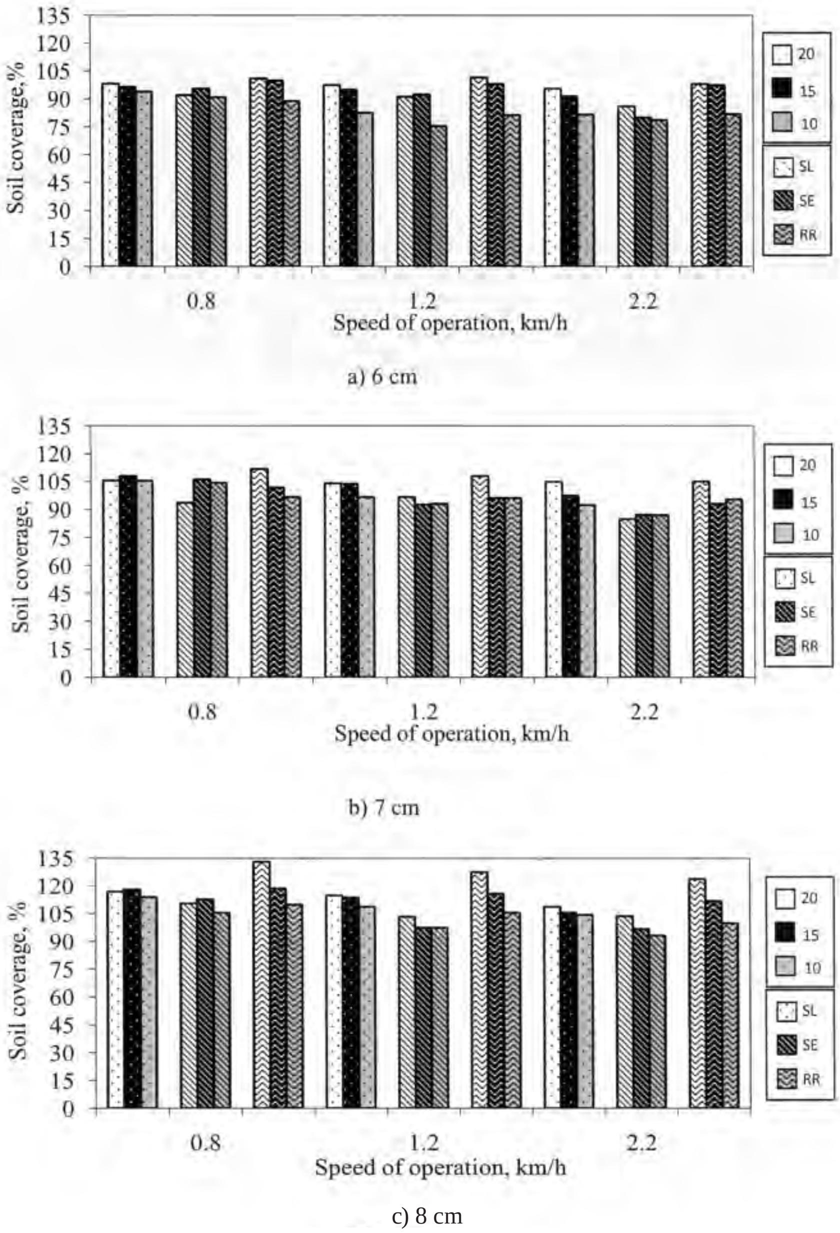


the tools and increased soil strength with increase in depth of operation, thus leading to higher draft and availability of more volume of soil for higher soil coverage of seedlings.

Effect of Closer Angle

It can be seen from **Figs. 5** and **6** that both draft and soil coverage of all furrow openers with DC increased with increase in angle of closer from 10 °C to 20 °C at any operating speed tried. Among the three angles tested lowest and highest draft values as well as lowest and highest soil coverage were observed for 10 °C and 20 °C DC angles, respectively. This was due to handling of more volume of soil by the disc closers with increase in closer angle.

Fig. 6 Variations of soil coverage in different types of furrow openers with disc closer at different depths, operating speeds and closer angles



Selection of Best Combination of Furrow Opener and Furrow Closer

The criterion for selection of best furrow opener and furrow closer was the combination which gave less draft and minimum required soil coverage, i.e. 100 %.

Effect of Opener Type on Draft and Soil Coverage

The results of statistical analysis (Duncan Multiple Range test, DMRT) was carried out to decide the best among the two groups of furrow openers with closer are given in **Tables 2** to **4**. It can be seen from these Tables that draft and soil coverage were minimum for SE opener and maximum for RR opener with both PC and DC. Draft for openers with PC was found lesser than openers with DC, while soil coverage was lesser than 100 % for all furrow openers with PC i.e. the seedlings dropped in the furrow were not covered properly (**Fig. 7a**). Hence, the next suitable furrow opener is SL type from the draft and soil coverage point of view. The draft and soil coverage of SL type furrow opener with disc closer were 28.1 N and 100.9 % (**Fig. 7b**) respectively as compared to 26.45 and 91.76 % with SL type furrow opener with PC. Though draft was 6.23 % higher but soil coverage was more than 100 %, hence, SL opener with DC was selected as suitable combination of furrow opener and furrow closer for vegetable transplanters with cup type metering mechanism handling pot seedlings.

Effect of Closer Angle of DC on Draft and Soil Coverage

The effect of closer angle on draft and soil coverage can be seen on DMRT output given in **Table 4**. From this table, it can be seen that both draft and soil coverage increased as closer angle of disc increased. Maximum coverage (104.4 %) was observed for 20 °C closer angle but with a higher draft requirement. Hence, 15 °C closer

Table 1 Vegetable transplanters along with the type of openers and closers

Organisations	Transplanter and seedlings types	Type of furrow opener	Type of furrow closer
TNAU, Coimbatore	Three row, plug type, semiautomatic	Shoe	Press wheel
CIAE, Bhopal	2-row, semiautomatic, bare root seedling	Runner	Press wheel
IIT Kharagpur	Hand tractor operated, fully automatic, paper pot seedlings	Shovel	Inclined M.S. plates
Dr. PDKV, Akola	Semiautomatic, bare root seedling type	Shoe	Inclined M.S plates
PAU, Ludhiana	2-row, tractor mounted, bare root seedling	Runner	Press wheel
BCKV, West Bengal	One row, power tiller operated, bare root seedling	Modified vertical tool	Miniature mould board

Table 2 Duncan Multiple Range Test for effect of opener type on draft

Opener type	Openers with PC			Openers with DC		
	Subsets			Subsets		
	1	2	3	1	2	3
SE	187.56			175.59		
SL		259.47			275.66	
RR			298.12			367.09

Table 3 Duncan Multiple Range Test for effect of opener type on soil coverage

Opener type	Openers with PC			Openers with DC		
	Subsets			Subsets		
	1	2	3	1	2	3
SE	86.71			94.5		
SL		91.76			102	
RR			96.98			103.7

Table 4 Duncan Multiple Range Test for effect of closer angle on draft and soil coverage for disc closer

Closer angle, deg	Openers with PC					
	Draft, N			Soil coverage, %		
	Subsets			Subsets		
	1	2	3	1	2	3
10	227.29			94.94		
15		274.38			100.9	
20			316.76			104.4

Fig. 7 Pictorical view of the planted seedlings at various speeds

a) Plate closer at 2.2 km/h b) Disc closer at 2.2 km/h c) At 3.2 km/h

angle of disc was selected as it gave the required soil coverage (100.9 %) with lesser draft compared to the draft at 20 ºC closer angle.

Conclusions

- Draft and soil coverage increased with increase in operating depth for all furrow openers tested with both plate closer as well as disc closer.
- Draft increased with increase in operating speed for all furrow openers with both plate closer as well as disc closer, whereas soil coverage slightly decreased as speed was increased.
- Speed of operation 3.2 km/h was found unsuitable for vegetable transplanter with cup type metering mechanism handling pot seedlings because seedlings were not falling vertically in the furrow.
- Both soil coverage and draft increased with increase in disc closer angle. Disc closer angle of 15 ºC was selected as it gave minimum required soil coverage (100.9 %) with lesser draft as compared to 20 ºC closer angle.
- SL opener with disc closer was selected as the suitable combination of furrow opener and furrow closer for vegetable transplanter with cup type metering mechanism as it was giving required soil coverage of 100 %.

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Performance Evaluation of Experimental Self-Propelled Double Row Sugarcane Harvester

by

Vaibhav Suryawanshi
Research Associate
vaibhav4fpm@gmail.com

Surinder Singh Thakur
Research Engineer
ssthakur3@yahoo.com

Ankit Sharma
Research Associate
ankitagrineer@gmail.com

Department of Farm Machinery and Power Engineering,
Punjab Agricultural University, Ludhiana-141004 INDIA

Abstract

India produces more than 340 millions tones of cane at an average rate of 70 tons per ha. It is grown by small, medium and big farmers, but 83 % of sugarcane growers fall in small holder category. Sugarcane harvesting is the single most expensive and labour intensive operation in sugarcane farming. Whole Stalk harvesting or Cut-chop harvesting are expensive systems and as such beyond the capacity of average farmer of developing countries. Most of the sugarcane farmers in developing countries use a handheld knife to cut the sugarcane stalks at the base level and green top by impact force. In some developing countries, including India, farmers are beginning to face labour shortages, because of recurring labour scarcity during harvest season. It is desirable to transport the harvested cane to the factory within 24 h, as the yield declines by 0.4 % per day after cutting. In this study an experimental self-propelled double row sugarcane harvester powered by an 8 hp diesel engine was used. The machine was evaluated for field capacity (ha/h), fuel consumption (L/h) and material capacity (t/h) as dependent parameters and forward speed (2 level), method of collection (viz. guide bar method and rope method) and cutter bar speed (3 level) as the independent parameters. The experiment was conducted for trench planted sugarcane crop. The optimum parameters were found at; forward speeds 1.0-1.4 km/h, guide bar and 1020 strokes/min of knife bar in trench plant cane.

Introduction

India is the second largest sugar producing country of the world. It occupies an area of about 4.41 mha (Anon., 2008a). India produces more than 340 million tonnes of cane at a national average of 70 tons per ha (Anon., 2008b). About 83 % of sugarcane growers are small farm holders (Sharma *et al*., 2006). Sugarcane plantations are concentrated mainly in nine Indian states, viz; Andhra Pradesh, Bihar, Gujarat, Haryana, Maharashtra, Punjab, Tamil Nadu, Uttar Pradesh, and Uttaranchal. The sugarcane harvesting season falls between August and January, but it varies from region to region, as India is a large country with two distinct climatic zones, one tropical and one subtropical, and sugarcane is grown differently in each of these zones.

Sugarcane harvesting is the single most expensive operation in sugarcane farming. Sugarcane harvesting is done by skilled workers who are well experienced in harvesting the cane in order to maximize sugar yield, and without damaging the cane stumps at the ground level as these are essential for the ratoon sugarcane crop. Manual harvesting involves cutting the stalks and removing the green tops, detrashing, bundling and loading of cane in transport vehicle.

In some developing countries, sugarcane farmers face acute labour shortage, during harvest season. Farmer often uses strategy of early harvest and stock piling of the harvested cane before delivery date to the sugar processing mills. In this process, some of the cane deteriorates in quality. Hence, it is desirable to transport the harvested sugarcane to the factory within 24 h, since the yield decreases by 0.4 % per day after cutting (Bhaholyodin *et al*., 1988).

Manual harvesting is also quite commonly used by Indian sugarcane growers. There is acute shortage of skilled manual labour, which is leading to considerable problems for Indian sugar mills. Sugarcane harvesting is a tedious task, and not very well paid. Hence, it is difficult for many plantations to find workers who can harvest the cane properly.

Mechanical harvesters are expensive to purchase, and also expensive to run. Mechanical cane harvesters are also large, heavy equipment that cause considerable soil compaction. Sugarcane needs medium to heavier soil in order to grow well. Cane harvesters also damage the roots of sugarcane far more severely and far more often than manual harvesters. Sugarcane roots are important, as they will sprout and grow again, sometimes up to twelve times, though this is an exceptional number and usually only associated with special strains of Brazilian sugarcane. The typical number of re-growth is between three and six. Destroying roots during the first harvest, therefore, represents a significant yield loss from a single planting. Sugarcane harvesting continues to evolve over time.

Cane harvesters are in wide use in countries like Australia, Brazil and America. These are broadly of two types, namely, Sugarcane Combines and Wholestalk Harvesters. Functions performed by combine are detopping, base-cutting, chopping, the cane stalk into billets, trash removal, conveying and loading. The whole stalk harvesters detop, base cut and windrow the cane stalks. Loaders subsequently pick up the windrow cane manually or mechanically. These machines are usually operated after burning the cane to reduce the trash content.

Sugarcane combines are usually self-propelled and generally require over 100 kW engine (Briscoc. 1970). Sharma and Singh (1985) designed and developed a rear mounted tractor operated sugarcane harvester. It cuts cane with ground level and windrows the harvested stalk. The capacity of the machine was 0.25 ha/h. Gupta *et al*. (1996) developed a self-propelled single-axle sugarcane harvester powered by 6 kW (8hp) gasoline engine. It was primarily developed for farmers of developing countries who cannot afford to purchase expensive sugarcane harvester used in developed countries. In the field test, the average field capacity of the machine was found to be 0.13 ha/h with average field efficiency of 71 %.

Thus, it may be appropriate to introduce a whole stalk harvester in view of its lower cost. However, this harvester may not include detopping because tops are used as an animal feed in many developing countries. Therefore, there is a need to develop a suitable harvester to suit local conditions and mechanize sugarcane harvesting in India.

Table 1 Specifications of double row Self Propelled sugarcane harvester

Particulars	Dimension/type
Name and type of machine	Self propelled, walk behind type
Engine	Diesel engine
Power source and type of cooling	8hp and air-cooled
Number and types of blades	12, serrated blades
Width of cut, mm	1,000
Number of gear	3
Power transmission	From engine through pitman shaft, which in turn drive the cutter bar
Dimensions	Overall length: 1000 mm
	Overall width: 800 mm
	Overall height: 1000 mm
Traction device	Double wheel, 4-10 inch.
Starting	By using rope
Controls	Brake, clutch, Forward and Backward direction

Table 2 Machine parameters

Independent Parameters	Levels	Values	Dependent Parameters
Forward speed	2	a) 1.00-1.40 km/h (F_1) b) 1.50-1.90 km/h (F_2)	Fuel consumption (L/h)
Method of collection	2	a) Guide bar method (M_1) b) Rope method (M_2)	Field capacity (ha/h)
Cutter bar speed	3	a) C_1: 550Strokes/min (C_1) b) C_2: 800 Strokes/min (C_2) c) C_3: 1020 Strokes/min (C_3)	Material capacity (t/h)

Materials and Methods

A double row, self propelled, walk behind type sugarcane harvester was developed and evaluated in the Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana during the year 2008-09. The specifications of the equipment are given in **Table 1**. The independent and dependent parameters selected for the study are given in **Table 2**.

Methods of Planting

There are three methods of planting, viz, flat-planting, furrow-planting and trench-planting.

Flat-planting

In this method, shallow furrows are opened with a desi plough, 80 to 100 cm apart; the setts are placed in the furrows end to end and covered with 5 to 7 cm of soil, and the field is leveled with a heavy plank (sohaga).

Furrow-planting

Furrows are drawn by a ridger, about 10 to 15 cm deep, in northern India and about 20 cm deep in Peninsular India. Setts are laid end to end in the furrows and covered with 5 to 7cm of soil, leaving the upper portion of the furrows unfilled. After planting and covering the setts, water is let into the furrows. In some parts of Tamil Nadu, particularly in heavy clay soils, water is first let into the furrows to soak its bed thoroughly and the cane setts are then dropped into the furrow and pressed into the mud by feet. In the case of monsoon planting, as a precaution against the stagnant water in the furrows damaging the buds, the setts are placed inclined on the side of the furrow, instead of flat at the bottom of the furrows.

Trench planting

Trenches, 20 to 25 cm deep with rectangular or trapezoidal in section, are made either by manual labour or by a tractor-drawn ridger; the bottom of the furrow is loosened by digging (**Fig. 3b**). Shallow furrows are made in the bed of the trench and the setts are placed end to end in the furrows and covered,by soil as in the case of flat-planting. Water is then let into the trenches. Trench-making, setts planting applying fertilizer and pesticides and covering the setts in the trenches are done simultaneously by a tractor-drawn planter.

In most parts of northern India and Bihar, and in the Malnad tract of Karnataka, cane is planted on flatland. Furrow-planting is practiced in parts of eastern Uttar Pradesh and in Peninsular India, and trench-planting is done in some coastal areas where the crop grows very tall and the strong winds are liable to bend the cane and damage them. Planting is done dry or wet. In the canes of dry method, irrigation is not applied at planting time or immediately after that, the planted setts germinate in the comparatively dry soil. In wet planting, on the other hand, the field is irrigated just before or after planting or at both times so that setts germinate in wet soil. Whether the furrows are irrigated before or after planting makes little or no difference. Indeed, in most cases the planted field gets additional irrigations to keep it wet throughout the period of germination.

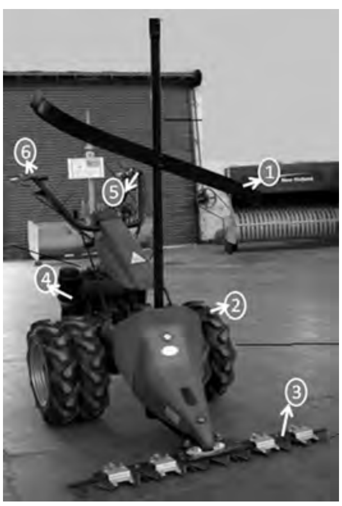
Constructional Description of the Harvester

A double row self-propelled walk behind harvester operated by 8 hp diesel engine was used to cut the sugarcane sticks of variety COJ-87 by using single acting reciprocating knife type cutter bar of 1m size. Power transmission to the cutter bar was provided by a pitman shaft which was connected to the engine through clutch and gear box. The desired cutter bar speed was maintained by means of a engine accelerator placed near the handle. Cutter bar worked on the principle of shearing of the cane stalks and cut sugarcane stalks close to the ground to minimize the losses. As the machine moved along the row, the cut cane stalks were laid in windrow by using the rope and guide bar method. Power to the wheels was provided from the engine through clutch and gear box. These all are on handle for easy and safe operation. The stationary view of the machine is shown in **Fig. 1**.

Method of Collection and Planting

A rope and guide bar method was used for windrowing the cut sugarcane stalks. For using the rope method, the rope was always placed inside the row. Hence some idle time was required for cutting of each cane and five labours were required for the operator. To reduce this labour requirement and time, a guide bar to windrow the cut sugarcane crop was developed which helped in labour and time saving. For the de-

Fig. 1 Sugarcane harvester machine



1. Guide bar, 2. Pnematic wheel, 3. Cutter bar, 4. Engine, 5. Break and, 6. Accelerator

Fig. 2 Schematic diagram of guide bar

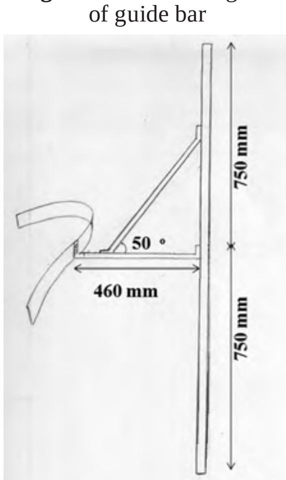


Fig. 3 Trench planting method

Fig. 4 Sugarcane harvester at the time of harvesting operation

velopment of the guide bar, MS Flat of size 3" × 1/4" and B class high pressure M.S. pipe of length 1.5 m length was used (**Fig. 2**). The field trials were conducted in a field with trench planted cane, with row to row spacing of 90 cm and 30 cm for alternate rows. A view of planting method is shown in **Fig. 3a**.

Experimental Layout and Evaluation Procedure

A 20 m long sugarcane row was selected for each cutting. Forward speed was selected along with the cutter bar speed and method of collection. Labour requirement was constant for rope and guide bar method, viz. 5 labours for rope method and 3labourers for guide bar method. Considerable time was required for providing the rope in the inter row spacing. The machine was run in the required speed in the chosen gear to cut the cane standing in row and required time to cut the row, fuel and weight of cut sugarcane stalk were recorded. Similar experiments were conducted on different combinations of parameters for cutting the sugarcane for every row in the sugarcane field. During field experiments, an auxiliary five litre fuel tank was fitted on the machine to monitor fuel consumption. The auxiliary tank was installed to a fixed mark on the tank before starting the operation in the field. After harvesting the plot, the machine was stopped and fuel tank was refilled to the fixed level with a 250 ml measuring jar. The quantity of fuel required for refilling was recorded and fuel consumption was calculated.

Results and Discussion

Effect of Forward Speed on Fuel Consumption

Effect of forward speed on fuel consumption for different methods of collection and cutter bar speed are given in a **Table 3** and trend shown in **Fig. 5**. In general, fuel consumption increased with the increase in forward speed. The maximum fuel consumption of 2.59 L/h was observed at forward speed between 1.50-1.90 km/h and at cutter bar speed of 1020 Strokes/min. The values of fuel consumption of 0.88 L/h and 0.92 L/h, were at observed at forward speed of 1.00-1.40 km/h and cutter bar speed 550 of strokes/min. The fuel consumption in trench planting was more because two rows of cane were cut at a time and the cane density was more.

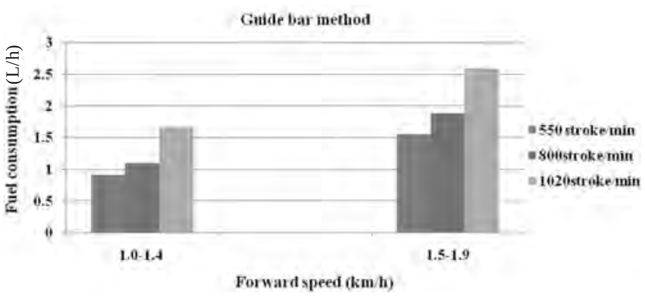
Effect of Cutter Bar Speed on Fuel Consumption

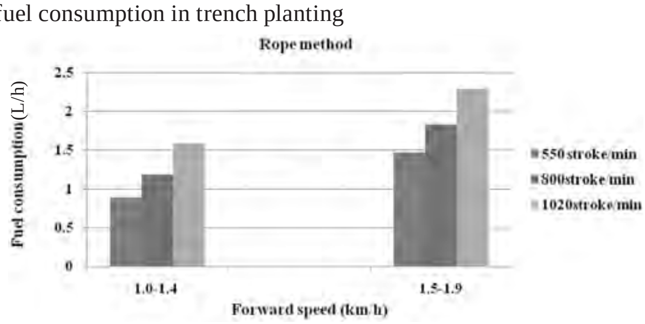
Effect of cutter bar speed on the fuel consumption for different methods of collection and forward speed is given in **Table 3** and trend shown in **Fig. 6**. In general, fuel consump-

Table 3 Experimental data of fuel consumption of sugarcane harvester in trench planting

Forward speed (km/h)	Method of collection	Cutter bar speed (Strokes/min)	Fuel consumption (L/h)			
			i	ii	iii	Avg
1.0-1.4 (1st gear)	Guide bar method	550	0.87	0.93	0.95	0.92
		800	1.05	1.13	1.11	1.10
		1020	1.66	1.80	1.54	1.66
	Rope method	550	0.87	0.85	0.93	0.88
		800	1.18	1.11	1.23	1.17
		1020	1.58	1.67	1.50	1.58
1.5-1.9 (2nd gear)	Guide bar method	550	1.44	1.57	1.65	1.55
		800	1.86	1.83	1.96	1.88
		1020	2.72	2.42	2.65	2.59
	Rope method	550	1.38	1.54	1.46	1.46
		800	1.77	1.76	1.92	1.82
		1020	2.17	2.35	2.27	2.29

Fig. 5 Effect of forward speed on fuel consumption in trench planting





tion increased with increase in cutter bar speed for each method of collection and forward speed of the machine. The values of fuel consumption were 1.69 and 2.59 L/h at cutter bar speed of 1020 strokes/min with guide bar method. The fuel consumption varied between 0.88 and 1.55 L/h at cutter bar speed of 550 strokes/min with rope method and at 1.50-1.90 km/h forward speed.

Table 4 Experimental data of Field capacity of sugarcane harvester in trench planting

Forward speed (km/h)	Method of collection	Cutter bar speed (Strokes/min)	Field capacity (ha/h)			
			i	ii	iii	Avg
1.0-1.4 (1st gear)	Guide bar method	550	0.055	0.055	0.054	0.055
		800	0.060	0.059	0.061	0.060
		1020	0.083	0.086	0.080	0.083
	Rope method	550	0.052	0.053	0.053	0.053
		800	0.064	0.063	0.061	0.063
		1020	0.076	0.078	0.075	0.076
1.5-1.9 (2nd gear)	Guide bar method	550	0.075	0.079	0.074	0.076
		800	0.083	0.085	0.082	0.083
		1020	0.112	0.105	0.107	0.108
	Rope method	550	0.069	0.071	0.070	0.070
		800	0.076	0.079	0.080	0.078
		1020	0.096	0.094	0.092	0.094

Fig. 6 Effect of cutter bar speed on fuel consumption in trench planting

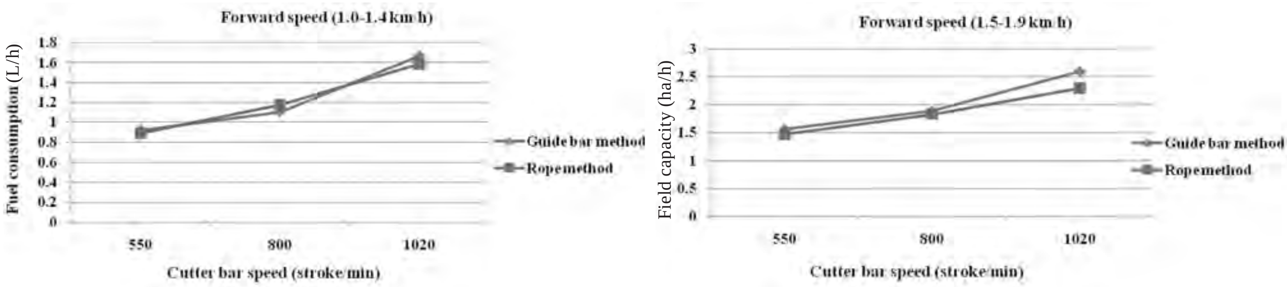
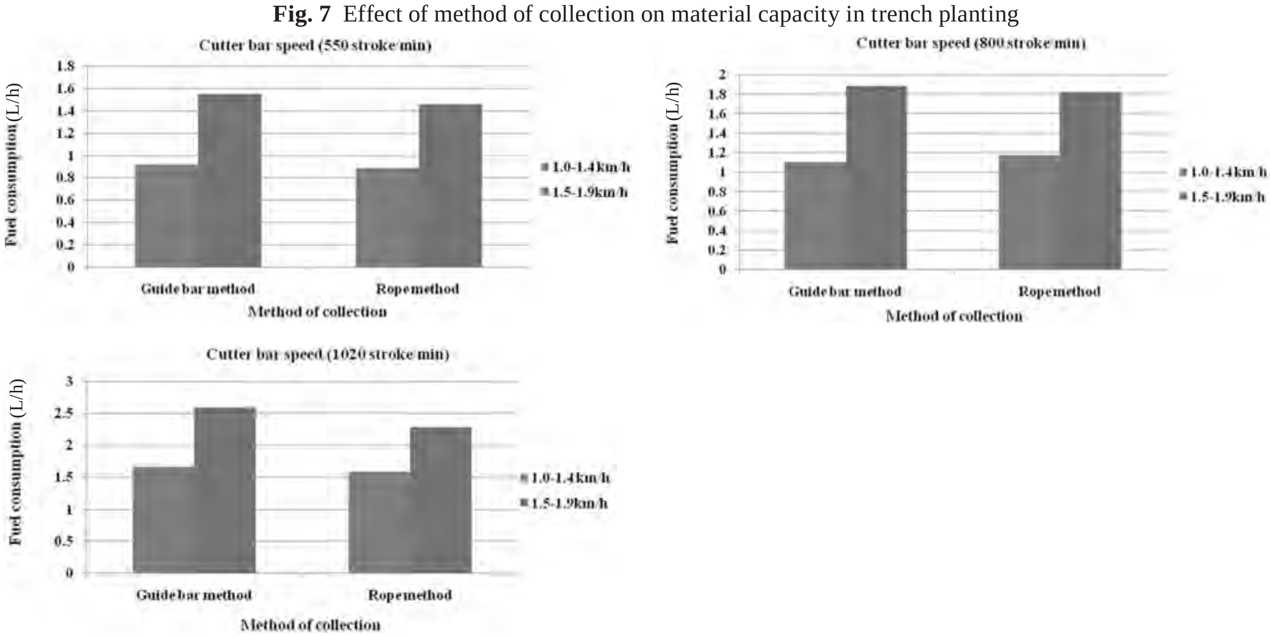


Fig. 7 Effect of method of collection on material capacity in trench planting



Effect of Method of Collection on Fuel Consumption

Effect of method of collection on the average fuel consumption at different forward speed and cutter bar speed is given in **Table 3** and trend shown in **Fig. 7**. In general, fuel consumption was more in guide bar method. From the data presented in **Table 3**, it was concluded that at cutter bar speed of 550 strokes/min and for guide bar method, when forward speed was 1.00-1.40 km/h, fuel consumption increased from 0.92-1.66 L/h. and at forward speed of 1.50 -1.90 km/h, fuel consumption increased from 1.55-2.59 L/h. Similarly for rope method, at forward speed of 1.00-1.40 km/h, fuel consumption increased from 0.88-1.58 L/h and at forward speed of 1.50-1.90 km/h, fuel consumption increased from 1.46-2.29 L/h.

Effect of Forward Speed on Field Capacity

Effect of forward speed on field capacity for different methods of collection and cutter bar speed is shown in **Table 4** and trend depicted in **Fig. 8**. In general, the field capacity increased with the increase in forward speed. The values of field

Fig. 8 Effect of forward speed on field capacity in trench planting

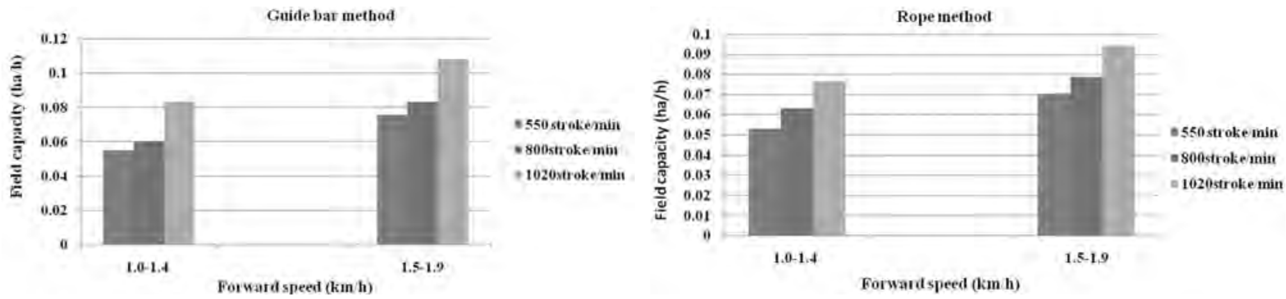


Fig. 9 Effect of cutter bar speed on field capacity in trench planting

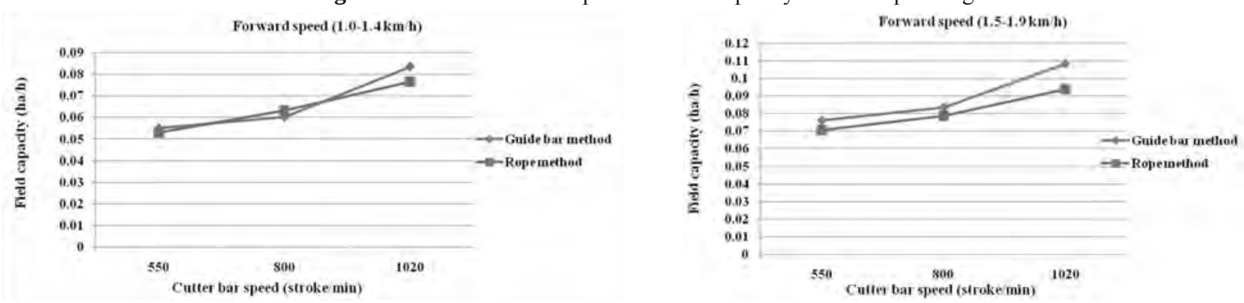
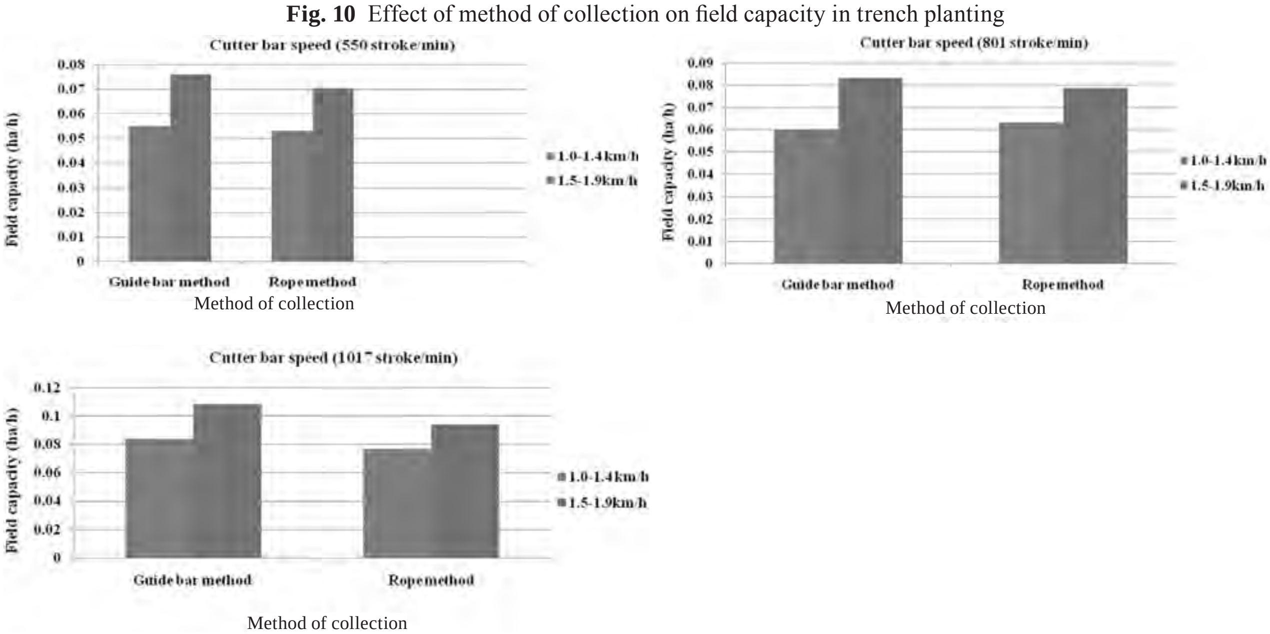


Fig. 10 Effect of method of collection on field capacity in trench planting



capacity were 0.076-0.108 ha/h at forward speed of 1.50-1.90 km/h and at cutter bar speed of 1020 stroke/min. The values of field capacity was 0.053-0.076 ha/h at forward speed of 1.00-1.40 km/h and cutter bar speed of 550 Strokes/min.

Effect of Cutter Bar Speed on Field Capacity

Effect of cutter bar speed on the field capacity for different methods of cane collection and forward speed is depicted in **Table 4** for flat bed planting, and trend shown in **Fig. 9**. In general, field capacity increased with the increase in cutter bar speed for collection and forward speed of the machine. The values of field capacity were 0.076 to 0.108 ha/h at cutter bar speed of 1020 strokes/min, for the guide bar method and forward speed of 1.50-1.90 km/h. The values of the field capacity varied from 0.053 to 0.076 ha/h at cutter bar speed of 550 strokes/min for rope method and at forward speed of 1.50-1.90 km/h.

Effect of Method of Collection on Field Capacity

Effect of method of collection on the field capacity at different forward speeds and cutter bar speed is shown in **Table 4** for flat bed planting, and trend shown in **Fig. 10**. The maximum values of field capacity was 0.083 ha/h and 0.108 ha/h at cutter bar speed of 1020 strokes/min for guide bar method at forward of speed 1.50-1.90 km/h. The minimum values of the method of collection varied from 0.053 ha/h and

Table 5 Experimental data of material capacity of sugarcane harvester in trench planting

Forward speed (km/h)	Method of collection	Cutter bar speed (Strokes/min)	Material capacity (t/h)			
			i	ii	iii	Avg
1.0-1.4 (1st gear)	Guide bar method	550	11.09	11.54	11.58	11.40
		800	12.53	11.36	12.59	12.16
		1020	16.39	18.29	17.35	17.34
	Rope method	550	11.07	11.00	11.60	11.22
		800	13.78	13.94	11.83	13.18
		1020	15.67	16.69	14.09	15.48
1.5-1.9 (2nd gear)	Guide bar method	550	15.53	14.77	14.28	14.86
		800	17.39	17.80	15.77	16.99
		1020	25.63	22.60	21.43	23.22
	Rope method	550	13.29	14.45	15.01	14.25
		800	16.47	15.47	16.58	16.17
		1020	19.67	18.51	18.62	18.93

Fig. 11 Effect of forward speed (Strokes/min) on throughout capacity in trench planting

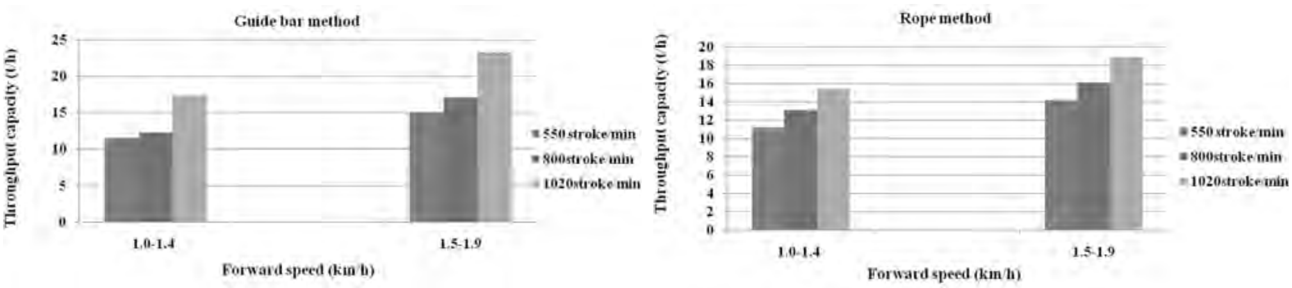
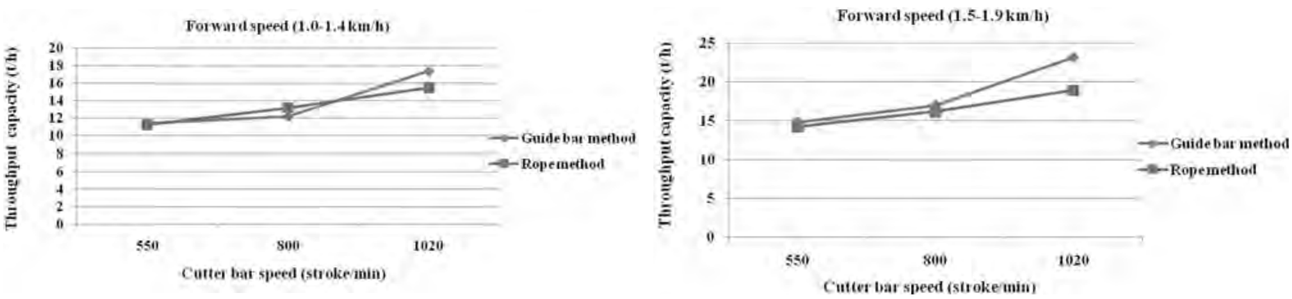


Fig. 12 Effect of cutter bar speed on throughout capacity in trench planting



0.070 ha/h were found at cutter bar speed of 550 strokes/min with rope method at 1.00-1.40 km/h.

Effect of Forward Speed on Material Capacity

Effect of forward speed on material capacity for different method of collection and cutter bar speed is shown in a **Table 5** and trend shown in **Fig. 11**. In general, material capacity increased with the increasing forward speed and cutter bar speed. The values of the material capacity varied between 18.93-23.22 t/h at forward speed 1.50-1.90 km/h, at cutter bar speed 1020 strokes/min. The values of material capacity were 11.22 t/h and 11.40 t/h, at forward speed 1.00-1.40 km/h, cutter bar speed at 550 strokes/min.

Effect of Cutter Bar Speed on Material Capacity

Effect of cutter bar speed on the material capacity corresponding to different method of collection and forward speed is indicated in **Table 5** of ridge bed planting and trend shown in **Fig. 12**. In general, material capacity increased with the increase in cutter bar speed irrespective of method of collection and forward speed of the machine.

Effect of Method of Collection on Material Capacity

Effect of method of collection on average material capacity at different forward speeds and cutter bar speed is shown in **Table 5** and trend shown in **Fig. 13**. In general, material capacity was more for the guide bar method. The values of material capacity for guide bar method were 17.34-23.22 t/h and for rope method 15.48-18.93 t/h, at 1.50-1.90 km/h at cutter bar speed of 1020 strokes/min. The values of material capacity for guide bar method varied between 11.40-14.86 t/h and for rope method between 11.22-14.25 t/h, at 1.00 to 1.40 km/h and cutter bar speed 550 strokes/min. The optimum operational parameters are shown in **Table 6**.

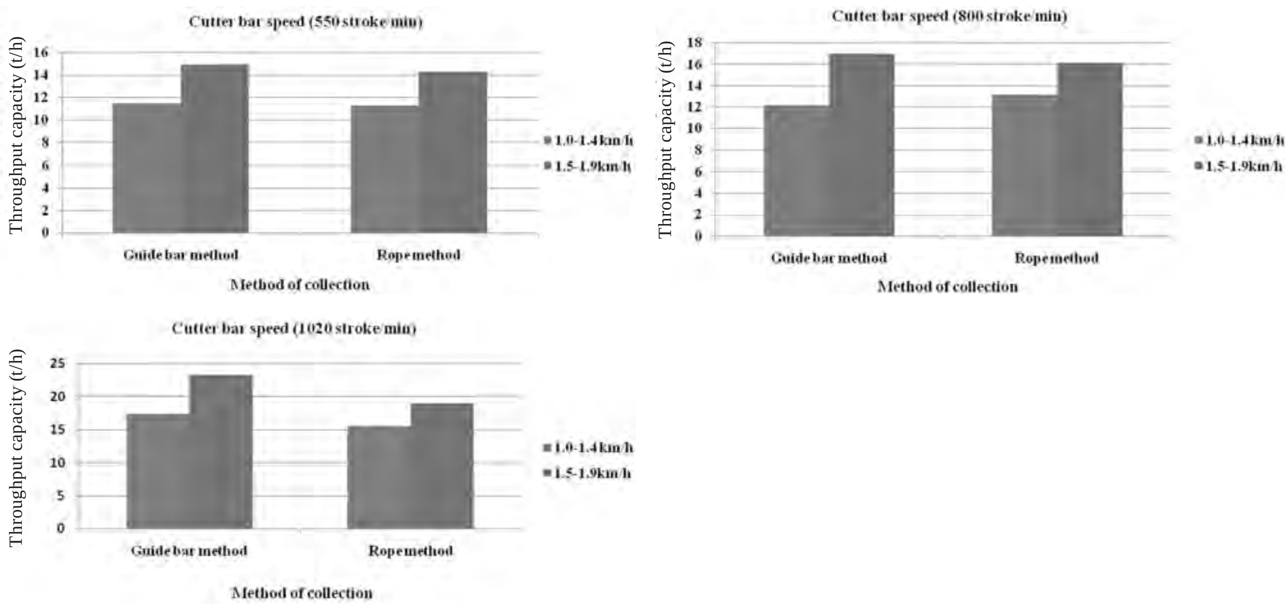
Conclusions

1. The experimental sugarcane harvester worked satisfactorily for ridge planting method.The fuel consumption was 1.53 L/h, field capacity 0.065 ha/h and throughput capacity was 9.87 t/h, at forward speed 1.00-1.40 km/h for the guide bar method.

Table 6 Optimum parameters for experimental sugarcane harvester

Trench planting					
Forward speed (km/h)	Method of collection	Cutter bar speed (Strokes/min)	Fuel consumption (L/h)	Field capacity (ha/h)	Material capacity (t/h)
1.00-1.40	Guide bar	1020	1.66	0.083	17.34
1.50-1.90	Rope method	1020	2.29	0.094	18.93

Fig. 13 Effect of method of collection on material capacity in trench planting



2. There was significant effect of forward speed on fuel consumption of the machine and it also increased due to increase in crop density. Field capacity and throughput capacity also increased with increase in forward speed.
3. Guide bar method of collection consumed more fuel than rope method, but the labour requirements (5 man-h/ha for rope method and 3 man-h/ha in guide bar method) were reduced by 66 %. This system comprised simple bar mechanism for guiding of cut stalks to one side to stop being crushed under the tires. The time required to insert the rope inside the crop was more; due to this the labour required in case of rope method was always more than that of guide bar method of handling the harvested cane stalks.
4. The harvesting operation was affected due to cane leaves, uneven row on ridge were major obstacle in the harvesting operation, while the lodged and irregular shape of stalk produced more split stalks.
5. The throughput capacity increased with the increase in the yield of sugarcane.
6. This harvester could cut the canes stalks, but labour was still required for detrashing operation.
7. The optimum operational parameters were, forward speed of 1.00 -1.40 km/h, guide bar method and cutter bar speed of 1020 strokes/ minute.

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Development and Evaluation of a New Double-Row Sugarcane Billet Planter with Overlap Planting Pattern

by
Moslem Namjoo
Instructor, Agricultural Machinery Department,
University of Jiroft, P.O. Box: 364, Jiroft,
IRAN
moslem.namjoo@ag.iut.ac.ir

Jalil Razavi
Assistant Professor,
Farm Machinery Department,
College of Agriculture,
Isfahan University of Technology, Isfahan,
IRAN

Abstract

A reduction in the amount of billet used in mechanized planting of sugarcane is very important. In this research a new billet planter which plants billets with an overlap planting pattern was fabricated. Array of cupboards attached on chain conveyor were used on two metering devices for transportation of billets to the furrows. The mechanism used to exclude extra billets was effective and at the same time simple in design and construction. Chain conveyor system enabled the timing of the billet travel to provide desired planting with the recommended billet overlapping. Ground-driven power train was used to run the metering devices, hence providing a constant billet overlap planting pattern according to the changes of forward speed. The planter was evaluated in the field based on the on cupboards filling percentage, over-overlapping and under-overlapping as affected by planting speeds (2.59, 3, 3.5, 4 km/h), cane varieties (CP69-1062 and CP57-614) and angles of the chain conveyor structure from vertical line (10, 15, 20 degree) with three replications. A factorial experiment in a completely randomized design was used to determine effect of planting speed and chain conveyor angle on cupboards filling percentage, over and under-overlap indexes. The results indicated that the chain conveyor angle and planting speed have significant effects on cupboards filling percentage. An increase in planting speed and chain conveyor angle decreased the percentage filling of cupboards. The best performance of the metering unit designed was obtained at a planting speed of 3.5 km/h for both varieties with a 20 degree conveyor chain angle.

Keywords: Billet Planter, Metering Unit, Overlap, Planting Uniformity and Sugarcane

Introduction

Sugarcane (Sacharum Officinarum L.) is a biennial crop and native of warm climates. The most important part of sugarcane is its stalks of which sugar is extracted [5]. Overall, 62 % of world sugar produced comes from sugarcane and 38 % from sugar beet [13]. Depending on geographical and climatic location, sugarcane may be harvested up to six years. Seed planting sugarcane is for developing new varieties while hole stalk and/or billet planting is for the purpose of sugar and byproducts production [2]. In billet planting often billets having 3 to 5 nodes are selected. At each node on the billets buds will appear from which stalks are grown and tillers may result. Billets placement on the planting rows inside furrows may be overlapped or none overlapped. None overlapping is when billets are placed horizontally on the soil surface one after another with longitudinal overlapping. If billets are placed with some degree of covering a part of each other, then the planting is the type of an overlapping pattern. The advantage of overlapping planting pattern is that if and when cutting stalks takes place between the nodes (internodes cutting), a 10 to 15 cm overlapping would result in a more uniform crop coverage after germination [6]. The number of billets planted per hectare depends on various factors including environmental conditions, variety, rate and method of irrigation, planting method and usually may amount to 15 to 20 thousands billets per hectares [2]. Planting may take place manually or by machine. Manual planting takes time and increases production costs. Because of labor shortages nowadays, manual planting only is practiced in small scale farming or for re-plantation of areas left with gaps; therefore, mechanized planting has become a necessity. Various planters are used for sugarcane planting. These mainly are billet planters and cutter-planters. In cutter planters whole stalk cane are fed to rotary cutters by labor and cut into certain desired length and then are placed on furrows. These machines may or may not make furrows and distribute fertilizers [12]. In billet planters equal length billets cut by harvester drum cutters go through metering devices which then transfer billets to ground surface. Metering devices are two types of precision meters and non-precision meters. Depending on metering device used on planters, billets are either planted uniformly (precision metering) or planted with a mixed or irregular pattern (non-precision metering).

Rajamohan (2002) developed a sugarcane planter in India which was of pulled type and had three separate holding tanks for pre-cut billets which were fed through a drop tube by three labours towards ground surface [11]. Tajuddin and Kavitha (2003) designed a pulled type planter with a field capacity of 2.5 to 3 ha/day. The metering device had two rotating drums capable of cutting whole stalk cane. Canes were fed to the drum through an inclined channel by labour. Drums holding cutters were powered by tractor PTO shaft. Billets planted were covered by soil after placement on the furrows by disk covers. Average billet length was 350 to 360 mm and average overlap length of consecutive billets placed on soil surface varied from 150 to 180 mm [15]. A one row planter with a tank holding 750 kg of sugarcane billets and 75 to 150 cm row width was designed in Egypt. The amount of overlap of billets planted was 25 % of the billets length [7]. In Pakistan, a planter was designed and developed to mechanize sugarcane planting operations. This machine was equipped with furrow opener and disk covers to cover billets planted with soil. Its metering device was capable of receiving billets from the tank and putting them on the soil surface in the furrows [16]. The Australian company, Austoft, developed a pull type double row planter having 2 ton capacity and capable of planting some 8 ton/ ha of sugarcane billets. The metering device was ground wheel driven and had a one meter belt on which metal cupboards to pick up billets from the tank were fastened. The cupboards were 50 cm in length and had 4 cm height [6].

Billet length is a factor which affects planting process and impacts mechanical damage to billets and tillers on them. As the length increases, the damage decreases. Damage to billets with an average length of 50 cm in manual planting is reported to be 11.4 % less compared to mechanized planting of billets with average length of 25.5 cm [14]. Use of overlap planting pattern besides accelerating germination process, would contribute to reduction or elimination of replanting operations if and when poor plant coverage due to gaps is observed. The rate of billet dropping by the metering device of any planter is an important factor from an economic stand point. Over dropping or over consumption of sugarcane billets is uneconomical simply because additional billets consumed may be processed to sugar with higher economic value. On the other hand, higher billet consumption results in less planting spacing and would require thinning later after germination which would increase production costs; while lower consumption reduces yield per area planted [1]. The aim of this research was to design and develop a new billet planter which plants billets of 50 cm length with an overlap planting pattern. The objectives of the research were:

- To reduce production costs by total mechanization of sugarcane planting operation,
- To reduce billet consumption,
- To reduce mechanical damage to billets.

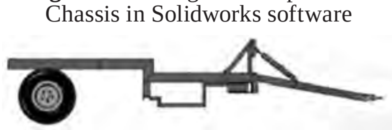
Material and Methods

Chassis Design

Design of agricultural machinery with specific goal of offering a solution for current problems in an agricultural region should consider certain important factors. The machine being designed should have simple flexible mechanisms with high degree of reliability and the least production costs. In next step, each and every component of the machine should have enough strength and be able to hold various loads exerted on them and at the same time have a good appearance in construction. In order to have a better design and higher fabrication quality, Solidworks software was used to model all parts and mechanisms [12]. Having considered the total geometry and dimensions based on holding tank volume and mass of each component, the assumed load on each part was entered into the model. Based on field conditions and each mechanisms type of work, the proper safety factor was considered in design having in mind the type of material being used in fabrication of the parts.

The chassis is considered to be as the main holding component of the planter various parts besides connecting to the tractor drawbar (**Fig. 1**). It should be designed in such a way that all other segments such as billet holding hoppers, metering devices, axels and wheels and power train are positioned in proper relation to each other. Since the chassis is faced with varying load exertion, selection of suitable material and shape and dimension for it is of great importance. Stress analysis should be applied to locate each and all parts and sections of the

Fig. 1 Modelling of billet planter's Chassis in Solidworks software



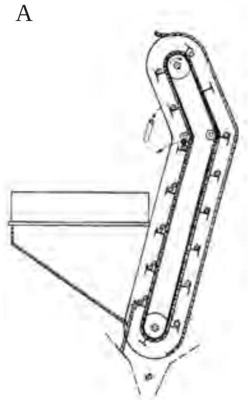
planter on the chassis. The chassis was designed to stand all bending and twisting loads. To increase its bending strength, its sectional momentum of inertia in line with the direction of bending was increased and for this purpose, length of the chassis was minimized, forces were concentrated close to the axle and C channel sections of were used in design of the chassis [13]. To avoid twisting of the chassis closed sections were used and longitudinal and cross anchors were applied deemed necessary [14].

Metering Device Design

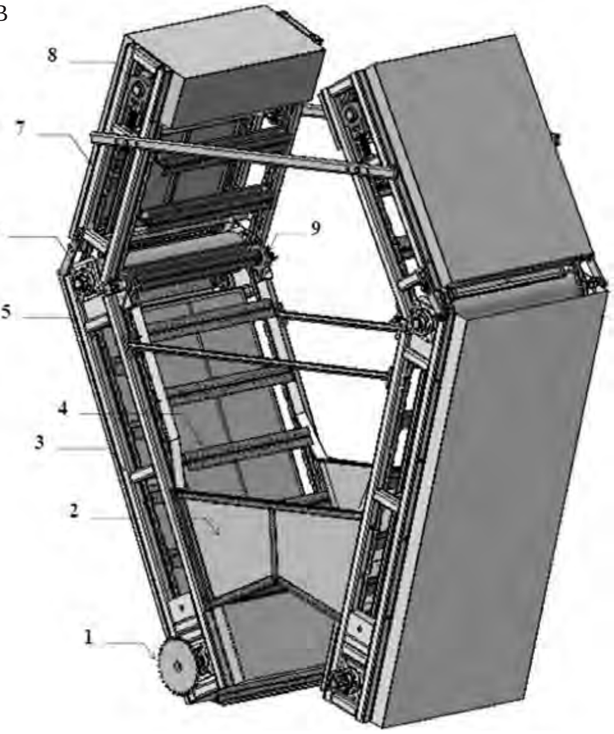
Metering device is the most important part of any planter because it should precisely count and uniformly distribute the seeds or in this case the billets. For billet planters, they should be able to plant billets with an overlap pattern or without any overlap. A metering device based on the mentioned goals and objectives above was designed and developed (**Fig. 2**). Each metering device consisted of two upper and lower chassis hinged in the middle to each other. This provided the possibility of changing the vertical angle of the upper chassis related to lower chassis which facilitates detachment of extra billets on each cupboard and transferring to holding tank. Timing of billets placement on furrows as desired with necessary overlap was made possible by combination of cupboards and chains matched with upper and lower chassis. The cupboards on conveyor chain had the job of carrying billets. Each billet was singularly picked up from the holding secondary tank and if more than one billet was in the cupboards, the additional one would be dropped out and returned back to the tank as the cupboard reached the middle section of the two chassis. When each billet reached top section of the upper chassis, it would drop on the back of the previous cupboard to be conveyed towards the soil surface. In this way, the job of detachment of extra billets would take place only in one point and by changing the vertical angle of the upper chassis [10].

Fig. 2a Schematic of metering unit and mechanism used for extra billets omission
2b Different parts of metering units

A



B



1. Chain wheel,
2. Secondary billet hopper,
3. Bottom chassis,
4. Cupboard,
5. Chain conveyor,
6. Flange bearing,
7. Top chassis,
8. Tensile bearing,
9. Idle chain wheel

Required Mechanical Power of Metering Device

Maximum power required to run the conveyor chain should be calculated when the chain system is at the position as shown in **Fig. 3**. To select power train components, mechanical power (Pm) required by conveyor chain was calculated using **Eqn. 1** [8].

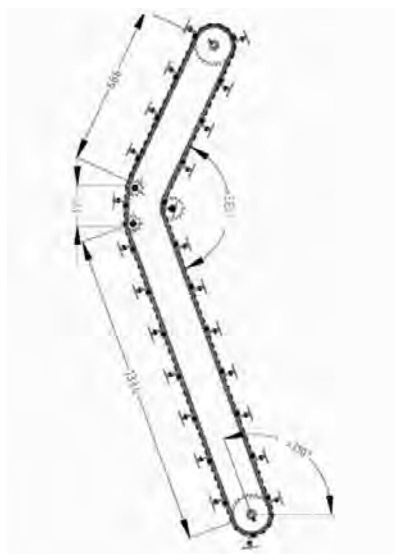
$$P_m = 2vL_cW_cF_c + Q\,(LF_m + H) \quad (1)$$

Where:

v: Linear chain speed (m/s)
L_c: Laid out horizontal length of the chain (m)
W_c: Chain conveyed mass per meter (N/m)
F_c: Chain rolling frictional coefficient
Q: Chain carrying capacity (N/s)
L: Laid out length of chain section under load (m)
F_m : Coefficient of friction of billets and metal surface
H: Height of billet conveyance (m).

Linear speed of the conveyor chain at its highest level was considered to be 0.54 m/s equivalent

Fig. 3 Metering device conveyor chain mechanism in maximum power utilization position



to 4 km/h for the planting speed on which all experiments were to be conducted. Linear mass of the chain was calculated using **Eqn. 2**.

$W_c = (2L_c w_c + n w_l) / L_c = (2 \times 4.584 \times 1.96 \times 9.8 + 24 \times 3.39 \times 9.8) / 4.58 = 212.26\ (N/m)$.(2)

Where:

L_c: Length of the chain (m)

n: Number of cupboards carrying billets

w_l: Mass of each cupboard (N).

Billet carrying capacity for 30 billets in 10 cupboards is calculated using **Eqn. 3** in which W_s is average mass of each billet.

$Q = 30 w_s / t = (30 \times 0.4 \times 9.8) / 3.56 = 33.03\ (N/S)$ ....(3)

Having coefficient of friction for billets on metal surface (0.42) and rolling coefficient of friction for the chain (0.39) and substituting for all variables in **Eqn. 1**, we will have power needed to run the conveyor chain as being:

$P_m = (2 \times 0.54 \times 1.2 \times 212.26 \times 0.39) + [33.03 \times (1.127 \times 0.42 + 1.88)] = 0.185\ (kW)$ ....(4)

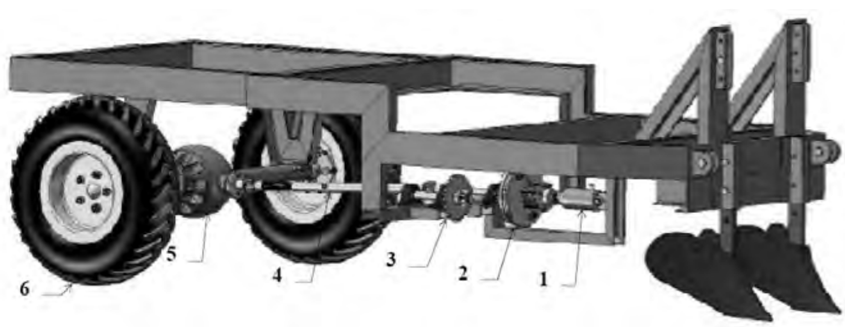
Power Train System

Power train system provides the required power for running the metering units, engagement and disengagement of the power and a change in sprocket ratios and reverse motion of the machine. **Fig. 4** shows various parts of the power train designed for the planter which transmits power from ground wheels to drive shaft of the metering units chains.

A clutch system has been used to engage and disengage power transmission from ground driven wheels to metering units and to protect the chains if they were in any cases overloaded. The clutch mechanism was selected to transmit the required power by metering units' chains and to engage and disengage as quickly as possible.

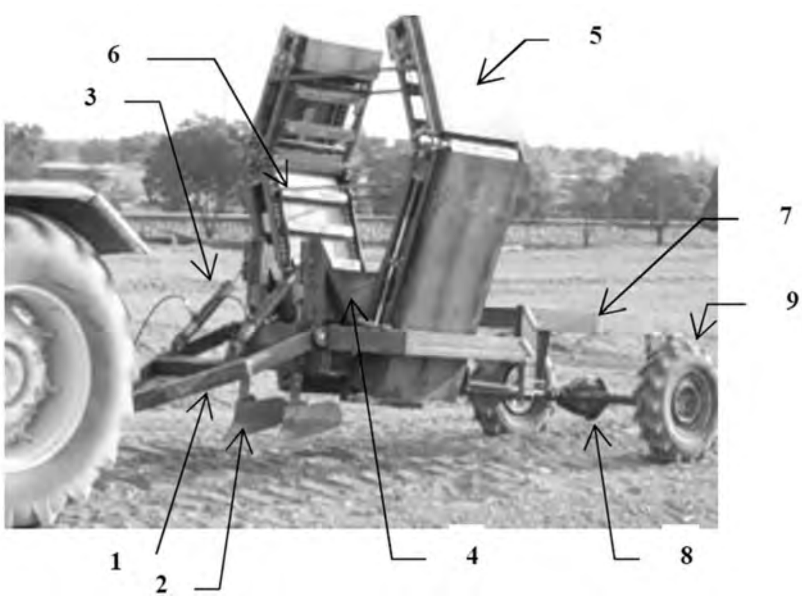
The gear ratio selected for the power train enabled to use 50 cm billets with an overlap of 12.5 cm as the billets were placed on the soil surface in the furrows. **Fig. 5** shows all sections and different parts of the planter designed and fabricated in this research.

Fig. 4 Different parts of the power train system



1. Hydraulic cylinder, 2. Clutch, 3. Chain sprocket, 4. Universal joint, 5. Differential, 6- Drive wheel

Fig. 5 Different parts of evaluated billet planter:



1. Drawbar, 2. Furrower, 3. Hydraulic cylinder, 4. Billet hopper, 5. Metering unit, 6. cupboard, 7. Chassis, 8. Differential, 9. Ground wheel

Field Evaluation

Field evaluation of the planter was done in experimental farm of the Isfahan University of Technology. For the purpose of evaluation of the fabricated sugarcane planter were considered in a randomized experimental design. Experiments were performed in three replications in plots of meters. After completion of each experiment, a measuring tape was used from the beginning to the end to record coordinates of each billet dropped on soil surface on a 20 meter length swath. Factors under consideration were:

A- Forward speed

Four forward speeds (2.59, 3, 3.5 and 4 km/h) was considered in this research.

B- Sugarcane variety

Billets used in this research were from two sugarcane varieties of CP69-1062 and CP57-614, the first having no debris and the second having debris.

C- Metering device's angle related to vertical angle

Performance of the metering device's conveyor chain angle at three levels of 10, 15 and 20 degrees from vertical angle was evaluated. **Fig. 6** shows the holes on the link which provided for change in angle.

Table 1 Summary of some physical properties of sugarcane billets

Itemu	CP57-614	CP69-1062
Billet Length (cm)	51.8 ± 2.45	52.1 ± 3.44
Billet Diameter (mm)	26.9± 2.16	27.4 ± 3.02
Billet mass per length (kg/m)	0.569 ± 0.18	0.612 ± 0.13

Biophysical Properties of Sugarcane Billets

To design the metering device for billet planter, certain biophysical properties of sugarcane billets were required. Fifty billets from two varieties were randomly selected and their weight, diameter and length were measured. Then, weight and average diameter were measured using **Eqns. 5** and **6**.

$$p = \frac{1}{50}\sum_{i=1}^{50}\left(\frac{m_i}{l_i}\right) \quad ....(5)$$

Where:
m_i: billet weight (kg)
l_i: billet length (m)

$$d = \frac{1}{50}\sum_{i=1}^{50} d_i \quad ....(6)$$

d_i: billet diameter (mm)

Mean and standard deviation for length, diameter and weight of billets used in experiments are given in **Table 1**.

Uniform spacing or placement of the billets on the planting row and pertaining overlap are important considerations in evaluation of billet planters. This relates to elimination of thinning or replanting operations which are costly. Several factors affect billets spacing from each other. The metering device might miss picking up billets from the holding tank or being unable to release it on the furrow at proper time which results in gaps between billets planted (under-overlap). On the other hand, the metering device might pick up a number of billets and deliver them to be placed on the soil surface which results in over-overlap planting pattern. In this research for each experiment after placement of the billets on the furrow, a tape was used to record beginning and end part of the billets to determine their longitudinal coordinates (**Fig. 7**). The power train system for the metering device mechanism was designed to provide 12.5 cm overlap as normal pattern of planting. The overlap pattern of planting of sugarcane billets lowers the risk of missing germination at nodes and therefore minimizing the cost of filling the gaps by labor in the later stages of plant growth. Values higher and lower than 12.5 cm would result in over-overlapping and under-overlapping, respectively. The aim of this research was to minimize these two patterns and bring it as close as possible to normal pattern. **Fig. 8** demonstrates three patterns of billet placement on the furrow.

Over-overlapping

According to **Fig. 9**, if the end coordinates of billet i was (X_2) i and beginning coordinate of next billet $(X_1)_{(i+1)}$, then the overlap would be:

$$P_i = (X_2)_i - (X_1)_{(i+1)} \quad ....(7)$$

If the spacing was greater than this value, it would be considered over overlapping and can be calculated by **Eqn. 8**.

$$O_{Over} = \left(\frac{\sum_{i=1}^{53}\left((X_2)_i - (X_1)_{(i+1)}\right) - 12.5}{950}\right) \times 100, \quad \text{if } [(X_2)_i - (X_1)_{(i+1)}] > 12.5 \quad ....(8)$$

Under-overlapping

If the spacing was lower than 12.5 cm, it would be considered under overlapping and can be calculated by **Eqn. 9**.

$$O_{Under} = \left(\frac{\sum_{i=1}^{53}\left(12.5 - \{(x_2)_i - x_{1\,(i+1)}\}\right)}{2000}\right)$$

Fig. 6 Adjustment link for upper chassis angle

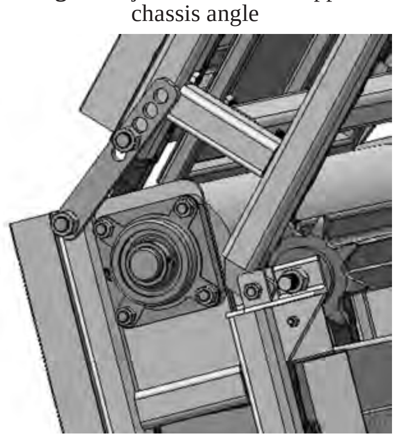
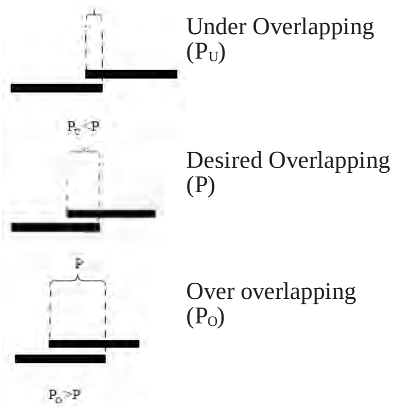


Fig. 7 Billets placement after delivery on furrow

Fig. 8 Patterns of placement of billets on the furrow



× 100,
if $[(X_2)_i - (X_1)_{(i+1)}] \leq 12.5$ .... (9)

Filling Percentage of Cupboards

An important parameter in evaluation of precision planters which plant one by one either seeds or billets is the filling percentage of the cupboards receiving from the holding tank. After each experiment number of billets on the furrow was counted on a distance of 20 meters which based on the design of the metering units and the power train should have been 53 billets as seen in **Eqn. 10**. The equation is used to calculate the filling percentage of each metering unit in which N is the number of the billets placed on the furrow.

$$\text{Filling Percentage} = (N/53) \times 100 \quad (10)$$

N = number of billets fallen on the furrow.

After calculation of research parameters, data was analyzed by SAS and MSTAT-C software and results were compared using LSD at 5 % level statistical significance.

Fig. 9 Calculation of under and over-overlapping

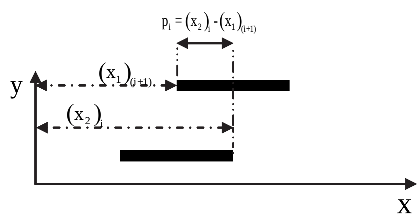


Table 2 Results of ANOVA test for factors affecting filling percentage, under and over-overlapping

Source of variation	df	Sum of Squares		
		Filling percentage	Under Overlapping	Over Overlapping
Angle (A)	2	243.55**	23.31	82.05
Variety (V)	1	262.83	186	1.7
Speed (S)	3	1063.52**	758.67	52.4
A*S	2	15.45	1.27	5.82
V*S	3	56.77	34.22	4.97
V*A	6	303.6	104.68*	15.5
V*A*S	6	9.25*	10.5	1.16
error	48	40.09	3.84	5.87

**And, *indicate significance at 1 and 5 % probability level.

Results and Discussion

Table 2 presents results of analysis of variance for the effect of forward speed of planting, angle of the metering device conveyor chain and sugarcane variety on filling percentage, over-overlapping and under-overlapping.

Filling percent of cupboards

Among factors affecting filling percentage of cupboards, effect of conveyor chain angle and planting forward speed was highly significant (P = 1 %) and interaction effect of all factors became significant at 5 % probability level. Effect of sugarcane variety on filling percentage was not significant. This may be explained by the fact that the size of cupboards was selected properly to hold billets firmly inside and with desirable stability until they are delivered to furrow, thus, no considerable effect on filling percentage due to changes in physical shape of billets as a result of sugarcane varietals characteristics.

Fig. 10 shows effect of planting speed on filling percentage of cupboards. As forward speed increases from 2.59 to 3 km/h, filling percentage decreases about 2.5 % which was not significant. However, as speed reaches 3.5 km/h, reduction in filling percentage becomes significant at 5 % level. Between speeds of 3.5 and 4 km/h the reduction in

Fig. 10 Effect of planting speed on cupboards filling percentage. Percentages followed by the same letters are not significantly different at the 5% level by LSD test

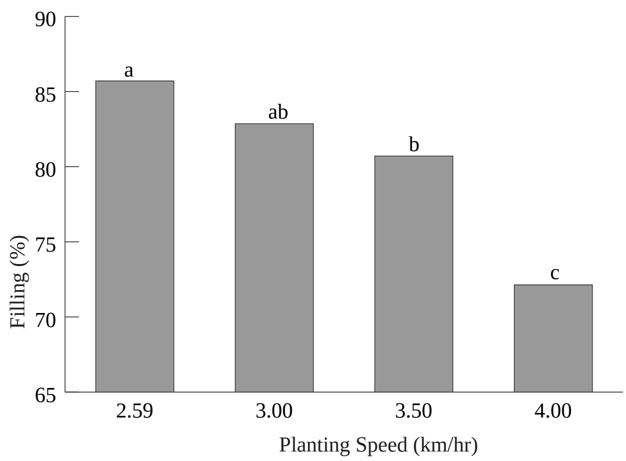


Fig. 11 Effect of chain conveyor angle on cupboards filling percentage. Percentages followed by the same letters are not significantly different at the 5 % level by LSD test

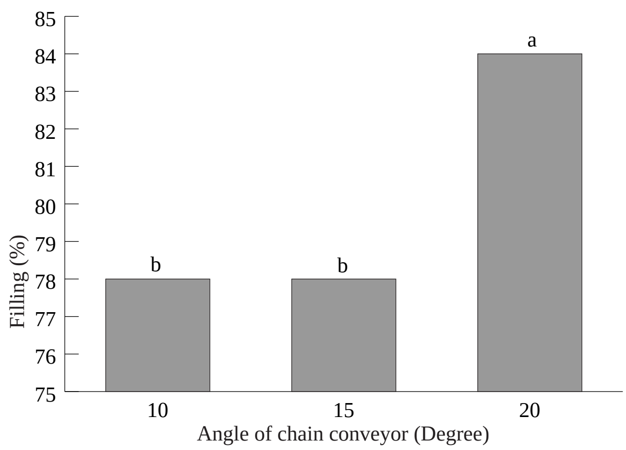


Table 3 Mean comparison of under and over-overlapping as affected by experimental factors

	Experimental factors	Under Overlapping	Over Overlapping
Speed of planting (km/h)	2.5	10.08 a	8.43 a
	3	10.00 a	8.17 a
	3.5	10.17 a	7.94 a
	4	9.12 b	8.40 a
Angle of chassis (degree)	10	9.29 a	8.35 ab
	15	9.96 ab	7.68 a
	20	10.23 b	8.66 b
Variety	CP69-1062	9.92 a	8.49 a
	CP57-614	9.72 a	7.98 a

filling percentage was also significant. As a whole, due to increase in forward speed from 2.5 to 4 km/h, filling percentage showed a 13 % reduction. This reduction may be as a result of lesser time given to each cupboard to pick up billets from the holding tank.

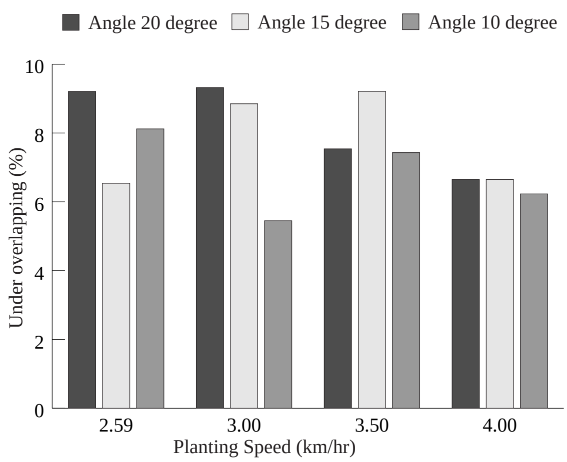
Fig. 11 shows the change in filling percentage of cupboards based on chain conveyor angle. An increase in angle of chassis from 10 to 15 degrees decreased filling percentage by 0.5 % which was not significant. But from 15 to 20 degrees an increase in filling percentage of 10.5 % was observed which was significant at 5 % level.

Percentage filling of cupboards at 20 degree angle of upper section of metering unit compared to 10 and 15 degrees angle was higher. The explanation for this condition is that at 20 degree angle may be more than one billet sits in the cupboard and also as the conveying chain rotates and any given cupboard passes the point of deflection where the lower and upper chassis are joined together, possibility of detachment of extra billets from the cupboard dimensions as compared to 10 and 15 degree angle. Transfer of more than one billet by each cupboard would increase filling percentage statistically [9].

Under-overlapping

Mean comparison of under overlapping as affected by experimental factors are given in **Table 3**. Only the interaction effect of forward speed and chain angle was significant at 5 % probability level. An increase in forward speed from 2.5 to 4 km/h resulted in 0.98 % reduction in under overlapping which was a significant difference. **Fig. 12** shows changes in under-overlapping under the influence of planting speed.

Fig. 12 Interacting effect of planting speed and chain conveyor angle on under overlapping



Over-overlapping

Mean comparison of over overlapping as affected by experimental factors are given in **Table 3**. According to the table, difference in mean over overlapping for various speeds did not become significant. Use of conveyor chain as compared to other mechanism and also installation of short distance cone shaped dropping tube has contributed to delivery of billets without any delay. Billets preparation during harvest operations for planting purposes is critical in terms of planting uniformity and cupboards filling percentages.

Billets should be of equal size in order for the cupboards to be able to pick them up at the right time without any restrictions. Cupboards designed and used in these experiments were able to pick up billets with various sizes. It should be noticed that placement of the billets on extreme right or left side of the cupboards would affect overlapping patterns under field conditions. Therefore, length of the cupboards should be enough to hold billets with different sizes.

Conclusions

The Results of Field Tests on a Billet Planter Indicated that:

Increase in planting speed would result in reduction of cupboards filling percentage. In this research increase in speed from 2.5 to 4 km/h resulted in 13 % in filling percentage.

An increase in metering device chain angle from 10 to contributed to increase in filling percentage of cupboards as much as 11 %.

The highest mean values obtained

for filling percentage and lowest mean values for under overlapping considering lower over overlapping, was with chain angle of 20 degrees and 4 km/h forward speed for without derbies billets. For billets with debris speed of 3.5 km/h is more appropriate to obtain better performances. Sugarcane variety had no significant effect on experimental factors.

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Development of a Mechanical Harvesting Aid for Prickly Pear Cactus Fruit

by
H. Ortiz-Laurel
Professor
Campus Cordoba
Postgraduate College
Cordoba, Veracruz
MEXICO
hlaurel@colpos.mx

D. Rössel-Kipping
Professor
Campus San Luis Potosi
Postgraduate College
Iturbide 73, Salinas de Hgo., SLP. 78600
MEXICO
edietmar@colpos.mx

Abstract

Mexico is the major global producer of cactus prickly pear fruit, harvesting 510,000 tonnes per year. Insufficient technology to bridge the gaps on production chain halts this agroindustry to reach its full potential. Hand harvesting of cactus fruit is greatly inefficient; it is slow and expensive, field conditions are arduous, unsafe and risky. Cactus plant is entirely covered with thorns, while cactus fruit has easily detachable microscopic hairs that stuck in bare skin; scaring off untrained workers. Inexpert handling of cactus fruit encourage injuries and yield losses amount up to 10 %. During hand harvesting, ripe fruits are grabbed by workers wearing rubber or leather gloves. Fruits are detached from the cactus plant by sliding a knife through the fruit's pedicel and then be dropped into buckets, conveyed from plant to plant until filled and then unloaded into pallet boxes for transport to storage. An innovative mechanism was designed which is assisted by a pneumatic system for creating a vacuum pressure inside a hose. When sucking, a yielding doughnut made of a thin flexible rubber placed at hose's end performs a gentle but firm grabbing rounding of the fruit, so bending *tunas* for cutting is easier and safer. Labourer does not touch the fruit at all. Glochids, although imperceptible they are vacuumed through the hose and trapped in a filter. All gears were installed over a trailer and the apparatus can couple four harvesting mechanisms without affecting pressure, allowing unrestrained movement of workers, simultaneously and independently of each other, and released them from the burden of carrying the bucket the whole harvesting day. Since apparatus is pulled between rows; workers walk along both sides of row, so labour productivity is increased up to four times. Mechanised harvesting of prickly pear cactus fruit, secures a safer work environment for labourers, increase labour producctiviy and higher income resulting in better quality fruit -being is delivered to the market.

Introduction

Cactus prickly pear fruit is named "*Tuna*" in Latin America. Worldwide, Mexico is the largest producer and consumer of cactus fruit. Around 20.000 small growers farm cactus prickly pear on 74,500 hectare in the low-rainfall regions of Mexico. Average yield of cactus fruit ranges from 7 to 8 tonnes per ha, with an annual production of 51,0000 tonnes (Flores Valdez, 2010). Marketable *Tunas* are typically 20-70 mm in diameter, round-, pear- or fig- shaped, and colour ranges from yellowish green to dark purple (**Fig. 1**) (Enríquez, 1994; Pimienta Barrios, 1994). Around 99 % goes to the fresh market, both domestic and international, and the remaining is utilized as raw feedstock for small food cottage industries to produce alcoholic beverages, sweet pancakes, jams and jellies (De la Rosa and Santamaría, 1998; Flores Valdez and Corrales García, 2000; Granados Sánchez and Castañeda Pérez, 1991). Yields of 25 tonnes or higher per ha could be obtained through good crop management and mechanized practices.

At present cactus plant management has progressed due to crop protection and fertilization because of mechanized technology (Gallegos Vázquez and Méndez Gallegos, 2000; García Herrera *et al*., 2003). Cactus plantation establishment has gone through a major change; four decades ago crop density was 2,000 plants per ha, leading to low yields, unbearable harvesting operation and poor pest control while nowadays a population of 625 plants per ha is the most well-liked array. Accordingly, each plant can produce from 30 to 40 kg of fruit per year; harvest is improved as well as fruit quality. Although, it is not hard to find other plantation arrays, which vary from separation between plant to plant along the row and distance between rows, so that, whatever the farmer's selected array it allows some mechanised operations. Several key factors have contributed to this break through in way of production; climate, environment, new varieties and better soils knowledge all coupled by scientific research for improving cultivation management, fertilizing, pest control, crop handling and storage, and government support to enlarge planted land, irrigation schemes and marketing for decision making in order to achieve profitability from this industry.

Despite those efforts, this agroindustry has not reached its full potential; its main weakness is short supply of adequate technology to bridge the gaps along the production-consumer chain (Lara López *et al*., 1986; Rössel *et al*., 2004). Alongside, domestic and international markets require both higher tonnage and better quality produce (Flores Valdez, 2009). Consequently, in order to assure required demand, production of *Tuna* is steadily growing in South America and North African countries, Israel, Italy, South Africa and Unites States.

Hand Harvesting of "*Tunas*"

In order to keep fruit harvest by hand, maximum height of cactus plant is kept at 1.8 m and diameter at 2.0 m through pruning. Cactus and cladodes (leaves or pads) are covered with stiff thorns all around, while *Tuna* has easily detachable microscopic hairs named glochids that easily stuck in bare skin; scaring off untrained workers (**Fig. 2**). Moreover, only "*Tunas*" of satisfactory size and maturity are selected for harvesting and have to be targeted and sorted out immediately (González Galván and Lara López, 1991). Thus, hand harvesting is dangerous for pickers because they have to manoeuvre around cactus and have to keep away from thorns while locating ripe prickly pear fruit ready to be detached (Escamilla Martínez and Lara López, 1991; Lara López, 1993). Furthermore, labourers do not wear any sort of protection for hands, arms or face at all. Therefore, harvesting is slow and expensive, also field conditions are arduous, unsafe and risky, and skilled labour is required for this operation.

Pickers prefer collecting *Tunas* early morning hours as soon as daylight allows them to manoeuvre safely all-round cactus plants for locating *Tunas*, because windless and misty conditions reduce the chances of glochids separation from fruit. Moreover, at that time of the day loose glochids are limp and harmless. Harvesting season extends from June to October, so shortage and extra demand for trained labour increases production costs (Méndez Gallegos *et al*., 1995). Losses up to 10 % are due to inexpert fruit handling which reduces storage self life, damage during transport and visual appearance, reduces farmers' income. On already established commercial cactus plantations harvesting costs represent 16-25 % of *Tuna's* production cost.

Harvesting costs vary according to productive region, on low yield plantations a worker can be paid USD $0.90 per each 25 kg fruit filled box (Flores Valdez, 2009). During hand harvesting, ripened *Tunas* are grabbed by workers wearing their sole safety outfit; rubber or leather gloves for handling the fruit. Two carry off methods apply; firstly, *Tunas* are grabbed and detached from the cactus pad by twisting them off gently breaking the fruit's pedicel, taking care not to damage the connecting pads and secondly, by holding the fruit, slightly bending it and sliding a knife through the connecting base to the cactus' cladode (Rössel *et al*., 2004). Once fruit is in the picker's hand, these are dropped it into buckets that they carryy from plant to plant until filled and then unloaded into field measuring boxes, ready for transportation to the selection, packaging and storage facility.

Knifed fruit separation from cactus is neatly performed and fruit was found with much lesser injuries than by twisting (Flores Valdez,

Fig. 1 Some varieties of cactus prickly pear fruit available in Mexico varying in size and colour

Fig. 2 Cactus's plants and fruit conditions for tuna harvesting

2010; Gallegos Vázquez and Méndez Gallegos, 2000). Fruit of good quality depends on reducing; skin and joint base damage while cut, height for fruit dropping, height for pouring the bucket and intense sweeping during removal of thorns and glochids (Escamilla Martínez and Lara López, 1991; Lara López *et al*., 1986; Lara-López *et al*., 1999; Méndez *et al*., 1995; Rössel *et al*., 2004). Therefore, it was necessary to design, manufacture and evaluate a sturdy, simple, more efficient and less fruit damaging harvesting aid mechanism in order to assist *Tuna* pickers safely perform their work, increase work productivity and consequently their harvesting income (Rössel *et al*., 2003; Rössel *et al*., 2008a; Rössel *et al*., 2008b).

Materials and Methods

Design for the Harvesting Aid Mechanism

Thus, the main criteria for developing a conceptual design prototype were (Rössel *et al*., 2003): 1. picker had to separate *Tuna* from cactus prickly pear without getting in touch with fruit, 2. increase harvesting capacity compared to hand harvesting, 3. damage to fruit has to be less or equal compared to hand harvesting, 4. low weight for the tool, 5. simple design for ease manufacturing, 6.tolerate unrestrained movement by pickers, 7. moveable, 8. reliable, 9. simple to use and repair, 10. low maintenance costs, 11. safe to operate, 12. feasibility of adding mechanical features, 13. feasibility of complete automation, 14. feasibility for developing a harvesting robot.

After a technological analysis pertained to customary engineering drive application and assessing its forthcoming economical and performance at field conditions, a pneumatic gear was chosen to be the central module for the whole system (Rössel *et al*., 2003). Pneumatics had been assumed to reduce damage significantly to the fruit and it could be the main component to begin with for an efficient semi-mechanized system and in the near future to be able to automate *Tuna* harvesting. Some major requirements for the machine were ease to adjust, to operate and maintain under actual Mexican field conditions (Rössel *et al*., 2008a).

All of those previous restrictions were studied and new approaches were sought to overcome them, especially to guarantee pickers a better and safer work environment. Beginning with that essential principle, an original mechanism was designed which consisted of a plastic nozzle closely coupled to a plastic pipe integrating a valve for altering air flow path and those were connected to a flexible hose (**Fig. 3**). Basically, for functioning the equipment required a vacuum effect inside a retaining hose which was generated by pneumatics gear. Accordingly, glochids problem either still attached to *Tunas* or freely flying on the air was significantly reduced. Labourer holding the suction hose and by just making a simple fling around and close to the *Tunas*, glochids are vacuumed, transported inside the hose and trapped in a filter (Rössel *et al*., 2008b).

The patented design mechanism nicknamed "kissing nozzle" performs two main functions (Rössel and Ortiz Laurel, 2009). The first one consists on making contact with the fruit which has to be as delicate as possible, likely to a smooth kiss. Contact is realized when a ring-shaped doughnut made of flexible rubber resembling a mouth with spongy lips, allows it to cover a larger surface around the fruit than the grip points made by the picker's fingers securing greater adherence to *Tunas* (**Fig. 4**). The second one, aided by vacuum suction, the tool makes a firm grabbing of the fruit which facilitate its manipulation, so it is safely bent to slice a knife between the portion that joins it to the cactus (Rössel *et al*., 2004). A good gripper ought to preserve the quality of the fruit. Position of "kissing nozzle" around fruit varying in size does not make unwanted effect when bending for knife cutting (**Fig. 5**). Once fruit retained by the nozzle has been separated from cactus, both are shifted over the collecting trays and fruit is release by closing

Fig. 3 Harvesting aid mechanism consisting of a nozzle activated by vacuum for grabbing a cactus prickly pear fruit

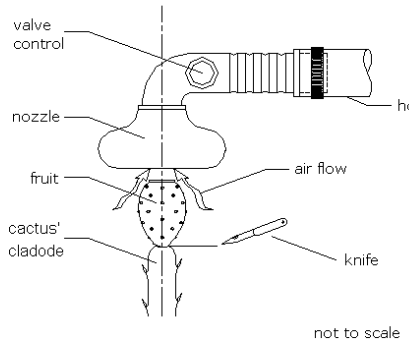

Fig. 4 "Kissing nozzle" holding a ripe tuna. Note size of fruit grabbed by the nozzle

the vacuum port through the valve.

Results and Discussion

Overall Construction and Field Testing

All elements for the prototype "Kiss Me" harvester were fitted together and installed over a wheeled trailer, with two wide open folding arms to carry the hoses high enough to pass over the cactus plant (Rössel *et al*., 2008a; Rössel *et al*., 2008b). The arms can be folded back according to harvesting needs and for road transport. Thus, additional cost of using a farm tractor or any other kind of motor vehicle for pulling the *Tuna* harvester between cactus rows is relatively low. Accordingly, this pick-up type vehicle is a common sightseeing in rural areas of Mexico because of its utilitarian character. Additionally, because of *Tuna* harvester has been provided with its own energy source for powering the pneumatics gear, its draught requirement is small and it is moving at a very low pace and it has to make continuous stops along the rows, eventually, it might be pulled by a pair of draught animals.

The whole assembly on the trailer consists of a gasoline engine, an air compressor, an accumulator for pressurized air, filters, pressure gauges, one-way-pass and safety release valves, pipes and hoses, collecting trays and all related accessories, as well as couplings for hoses and gripping nozzles positioned at hoses' ends (**Fig. 6)**. The trailer platform has been adapted to be utilized as a field container for harvested fruit, so labourers are relieved from the burden of carrying a bucket that they have to convey from plant to plant.

This "Kiss Me" harvester has a cost of USD $4,200 to build. From an economic analysis for investment return, it was found that because of shortness of harvesting season, depreciation of machine can be securely achieved through an annual use on 50 ha and its expectance usage life extends for 5 years.

The apparatus accepts coupling up to four harvesting aid mechanisms without compromising air pressure, allowing four workers operate simultaneously and independently of each other. With this configuration each worker can have up to 2.0 meters autonomy away from the connecting socket. Since, harvester is pulled between rows; workers can be positioned along both sides of cactus rows. In this way, labour productivity is increased up to four times compared to hand harvesting (Rössell *et al*., 2008b).

Conclusions

It was acknowledged that whatsoever instrument was built, it had to be manipulated by the labourer walking in the field around the plant and capable of operating a knife for cutting the fruit's segment attached to cactus. However, labourer does not touch the fruit at all. The kissing gripper guarantees a firm grip without damaging the fruit and serves in fact as the mouth of a vacuum cleaner. The resistance, capacity and size for all the harvester's components were chosen in order to allow attaching up to four harvesting mechanisms without compromising vacuum pressure, allocate four workers that operate simultaneously and independently of each other. From the technological aspect, results obtained reassured the advantages of mechanised harvesting of prickly pear cactus fruit, as well as granting a safer work environment for labourers, increase productivity as well as profitability and high quality fruit delivered to the market. However, by adopting innovation technology for harvesting of cactus prickly pear will require major changes on cactus plantations.

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Fig. 5 Kissing instrument can rest anyplace round the cactus fruit

Fig. 6 Whole assembly for mechanical harvesting aid for tunas in the field

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The Effect of Tractor Load and Trafficking on Wheat Crop Yield

by
S. K. Patel

Asstt. Professor, AAU, Anand,
Gujarat, INDIA
skpaau@gmail.com

Indra Mani

A. P. Srivastava

Principal Scientist, IARI, New Delhi
INDIA

Abstract

An experiment was conducted to study the tractor tire load and its frequency on wheat crop yield. A 39 plot experiment consisting of 13 treatments; a control with zero traffic and 12 treatment combinations made up of three normal loads, e.g. 4.40, 6.40 and 8.40 kN on tractor tire and four number of tractor passes i.e. 1, 6, 11 and 16 were used in the experiment. The experiment was laid using a completely randomized block design in a uniform field with sandy loam soil with alluvial texture. Wheat crop was sown after tilling the soil in the top 15 cm of soil. The crop parameters such as germination count, tiller count, plant height and crop yield were measured. After 18 days after sowing the germination count was same (40 number) in all plots as compared to control plots in each treatment. The number of tiller, plant per meter row and height decreased with increase of tractor tire load and its frequency and also significant at 1 % level of confidence interval. The influence of varying number of passes as well as normal load on grain yield was significant at 1 % level of confidence.

Key word: Sub-soil, Tractor load, trafficking, Wheat, crop yield,

Introduction

Proper plant growth requires good physical soil properties including texture, structure, organic matter content and high strength is needed. The major soil parameters that affect uptake of moisture as well as nutrient and in turn, plant growth, are bulk density, hydraulic conductivity and soil strength. The desired soil density for appropriate growth of different crops ranges between 1.4 to 1.80 Mg/m^3 for different soil types. Higher the soil compaction more is the bulk density as well as soil strength (Arvidsson *et al*., 2001; Ishaq *et al*., 2001). Compaction alters many other soil physical conditions in the field e.g. decreased total porosity, size and continuity of the pores (Hillel, 1982; Smucker and Erickson, 1989; Servadio *et al*., 2001) limited nutrient uptake, reduced water infiltration and its uniform redistribution. Parameters like air exchange, seedling emergency and root development (Dürr and Aubertot, 2000, Arvidsson *et al*., 2001; Ishaq *et al*., 2001) get diminished with increase in compaction resulting in decreased yields (Arvidsson *et al*., 2001; Radford *et al*., 2001; Dauda and Samari, 2002). However, it is less clear to what extent high soil strength can be considered as a primary constraint to crop growth. Evidence that this is the case has been obtained from sand-culture experiments (Materechera *et al*., 1991; Whalley *et al*., 2006), where soil strength was adjusted independently of water stress, and also from experiments where the confining pressure in the root zone was increased during plant growth (Young *et al*., 1997). Interpretation of plant responses is complicated by the fact that soil strength and water stress (matric potential) are highly correlated (Whalley *et al*., 2007; Taylor and Ratliff 1969), making it difficult to identify whether the plant is responding to low water availability or to high soil strength (Whalley *et al*., 2006). The aim of the paper is to test the hypothesis that sub-soil compaction reduces the crop yields.

Materials and Methods

Experimental Site

A study was undertaken to determine the effect of tractor tire loads and its frequency on wheat crop yield. A 39 plot experiment consisting of 13 treatments was laid using a randomized complete-block design in a uniform field of the experimental field during the period of 2006-07 and 2007-08. The experimental site is situated at 28.38 °N, 77.2 ºE and is at an altitude of 228.7 m above sea level. The climate of the experimental site is semi-arid and subtropical with hot summers and cool winters. The mean monthly maximum and minimum temperatures during the year range from 3.9 ºC to 45.0 ºC and 6.0 ºC to 8.0 ºC, respectively. There is an occasional occurrence of frost in December and January. The annual normal rainfall is 708.6 mm of which on an average 597 mm (84 %) is received from June to September. The soil of the experimental site has been classified as alluvial soil group and is of sandy loam texture. The major characteristics of this soil are given in **Table 1**.

Experimental Procedure

To achieve different sub-soil compaction level, tractor was run for different number of passes in the field on the same track and at varying normal loads on the rear tire. These 12 treatment combinations and a control of zero traffic were used in three replicates of a randomized block design. A factorial randomized block design was followed in laying the experiment and care was taken that all 13 treatments and their replications were included in field experiments. The plots of dimension 10 × 5.0 m were separated by alleys of 10 × 1.00 m. Before sowing the crop, soil was tilled the top 15 cm of soil. The sowing of wheat crop PBW 343 was completed in the experimental. Standard agronomical recommendations were followed for the application of fertilizers (NPK-120, 60 and 40 kg/ha). No variation in input rate was allowed among the plots and the only variation was of compaction level due to varying level of load and passes, The crop parameters such as germination count, tiller count, plant height, crop yield and root length density were measured. The germination count was recorded after 18 days of sowing. Number of plant per meter row and number of tiller per plant were counted after 90 days of sowing in respective plots. The grain yield was measured after harvesting the crop. A crop cutting experiment was conducted to determine the grain yield from different plots.

An analysis of variance was conducted to determine influence of study variables and their interaction on performance parameters using an SPSS programme. The F-value and thus test of significance of the study variables i.e. normal load, number of passage and their interactions on crop parameters were also evaluated.

Results and Discussion

A germination count of wheat crop was observed after 18 days after sowing. It was observed that the germination count was same (40 number) in all plots as compared to control plots in each treatment this was due to the fact that before sowing the wheat crop soil was tilled to a depth of 15 cm and all other crop inputs were same in all different plots.

The number of plant per meter row decreased with increase of normal load and number of passes. The number of plants per meter 90 days after sowing were 133 and 127 in the plots with 4.40 kN load of tractor tire for 6 and 16 pass of tractor tire, respectively in the same order (**Table 2**). Similarly, number of plants per meter row were 132 and 126 at 6.40 kN load on tire-soil interface for 6 and 16 pass of tractor tire, respectively. In case of 8.40 kN load of tractor tire for 6 and 16 pass of tractor tire were 131 and 125 plants per meter row, respectively. The plant per meter row decreased because initially all the seeds got germinated but 90 days after sowing growth of the crop diminished due to less sub-surface water availability due to poor root growth in compacted plots. It was observed that the plant per meter row due to number of passes was significant at 1 % level.

Number of Tiller per Plant

The number of tiller per plant decreased with increase in sub soil compaction level (**Table 3**). The total number of tillers per plant was measured at 90 days after sowing. The number of tiller per plant were observed as 3.8 and 3.5 in the plots for 4.40 kN normal load and test tractor run of 6 and 16 number of

Table 2 Number of Plant per meter row

Passes / Normal load, kN	Number of plant per meter			
	1	6	11	16
4.40	135	133	130	127
6.40	134	132	129	126
8.40	132	131	128	125

Table 1 Particle size distribution (sandy loam to loam)

Depth, cm	Bulk density, Mg/	Coarse sand, %	Fine sand, %	Coarse silt, %	Fine silt, %	Clay, %
0-21	1.41	0.95	49.00	24.05	11.50	12.75
21-52	1.41	0.50	54.35	22.70	8.50	12.25
52-93	1.41	0.60	53.75	20.50	9.63	13.00

Table 3 Number of tiller per plant Passes

Normal load, kN \ Passes	Number of plant per meter			
	1	6	11	16
4.40	4.0	3.8	3.8	3.5
6.40	3.8	3.5	3.3	3.3
8.40	3.5	3.5	3.3	3.3

Table 4 F- value for crop parameters

Source	df	Soil depth, cm			
		Plant/m row	Number of tiller	Height	Grain yield
load	2	1.997	1.964	36.451**	6.243**
pass	3	10.360**	1.246	23.968**	12.059**
load* pass	6	0.049	0.106	0.748	0.139

**significant at 1%, *significant at 5%, others non significant

passes, respectively (**Table 3**). The number of tiller per plant also followed similar trend and in general, the number of tiller per meter decreased with increase in tractor load and number of passes. When compared with tiller per plant in control plot, a maximum of 17.5 % decrease in germination count was observed due to 8.40 kN normal load and 11 pass of tractor tire. No difference in tiller per plant was observed in case of 1 pass and 4.40 kN load when compared with control plot. Thus, although marginal difference in number of tillers per plant was observed but statistically there was no significance difference in tiller per plant due to different level of sub-surface soil compactions in the field (**Table 4**). This was due to the fact that variation in tiller per plant was not large in absolute term but that didi not reduce the scope of adverse effect of compaction on total plant population once considered on per hectare basis.

Plant Height

Akin to other plant growth parameters, in general, a decrease in plant height was observed in the plots with large number of passes and higher amount of loads in tractor tire load as well as number of passes of tractor. A maximum of 12.53 % and minimum of 1.26 % decrease in plant height was observed at the time of harvesting due to application of sub-surface soil compaction caused by 8.40 kN load on tractor with 16 pass and 4.40 kN load on tractor for 1 pass of tractor, respectively in the same order (**Table 5**). For a load of 8.40 kN normal load with 1 pass of tractor the plant height was 80.4 cm followed by 78.4, 77.5 and 76.3 cm at 6, 11, 16 pass of tractor tire, respectively. At the time of harvesting the maximum plant height of 87.2 cm was observed in control plot whereas in highly compacted plot the same was 76.3 cm. The compaction level (combination of load and number of passes) on plant height was significance at 1 % level of confidence interval (**Table 4**). The treatment of less sub-surface soil compaction gave comparative height with control plot. In fact, the differences in loads and passes were not very large that is why statistically there was not much difference.

Grain Yield

The yield from different plots having treatments of varying normal load on tractor and different levels of passes was determined. The grain yield data were recorded after harvesting the crop by taking sample from per square meter area. Similar to other plant growth parameters the wheat yield decreased with increase of sub surface soil compaction. The maximum grain yield of 5,149 kg/ha was obtained in control plot. The yield decreased with increase in number of passes even at no additional load on tractor i.e. normal load of 4.40 kN. The observed wheat yields in the plots with 6 and 16 number of passes were 4,732 and 4,324 kg/ha, respectively (**Fig 1**). At 6.40 kN normal load a maximum 17.01 % decrease in yield was observed when the yield from the plot with 1 pass was compared with the yield of plot with 16 pass: the difference was 16.40 % when a normal load of 8.40 kN was considered for the same change in passes. From statistical analysis angle, the influence of varying number of passes as well as normal load on grain yield was significant at 1 % level of confidence interval but the interaction of normal load and number of passes on grain yield was not significant. In fact, crop growth and yield were influenced by many other soil and climatic factors hence direct correspondence in compaction

Fig. 1 Crop yield at different level of normal load and passes

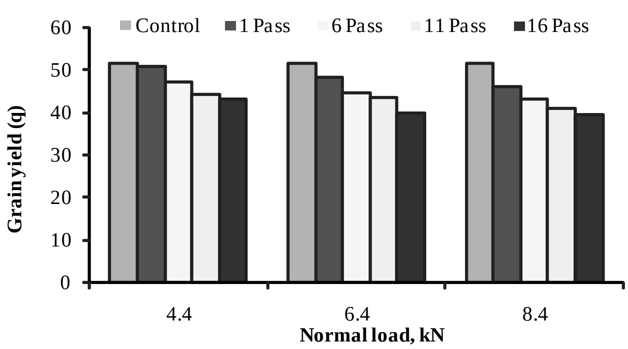

Table 5 Plant height at the interval of 20 DAS

Treatment		40 DAS	60 DAS	80 DAS	100 DAS	120 DAS
Control		32.7	46.7	67.9	83.7	87.2
4.40 kN	1 Pass	32.0	45.9	66.2	83.0	86.1
	6 Pass	31.0	43.7	64.6	81.6	84.5
	11 Pass	30.5	42.9	63.0	78.4	82.1
	16 Pass	30.0	42.5	62.5	76.8	80.1
6.40 kN	1 Pass	29.4	41.7	63.4	81.4	84.3
	6 Pass	29.1	41.3	60.8	77.1	80.6
	11 Pass	28.9	41.2	59.6	76.1	79.2
	16 Pass	28.6	41.0	58.5	74.7	77.5
8.40 kN	1 Pass	28.9	41.4	59.9	77.1	80.4
	6 Pass	28.0	40.7	57.8	75.4	78.4
	11 Pass	27.9	40.2	57.3	74.6	77.5
	16 Pass	27.4	39.9	56.1	71.4	76.3

and yield was not obtained however, the increasing level of compaction did influence the crop growth parameters including yield.

Conclusions

1. Compaction did not affect germination. After 18 days after sowing the germination count was same in all plots as compared to control plots in each treatment.
2. A maximum of 17.5 % decrease in germination count was observed due to compaction by 11 passes of tractor with 8.40 kN normal load at soil tire interface.
3. The yield decreased with increase in number of passes at all load and pass combinations. The observed wheat yields in the plots with 6 and 16 number of passes were 4,732 and 4,324 kg/ha, respectively
4. A maximum 17.01 % decrease in yield was observed at 6.40 kN normal load when the yield from the plot with 1 pass and 16 pass plot.
5. The difference was 16.40 % when a normal load of 8.40 kN was considered for the same change in plot which has 1 pass and 16 pass.
6. The influence of varying number of passes as well as normal load on grain yield was significant at 1 % level of confidence interval.

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Design, Development and Evaluation of Self Propelled Garlic (*Allium Sativum* L.) Clove Planter


by
Brajesh Nare
M. Tech,
Department of Farm Machinery and Power Engineering,
JNKVV, Jabalpur, INDIA
brajeshagengg@gmail.com


Atul Kumar Shrivastava
Professor and Head,
Department of Farm Machinery and Power Engineering
College of Agricutural Engineering
JNKVV, Jabalpur, M P INDIA
atul_jnkvv@yahoo.com


Rajesh Kumar Naik
Scientist,
Faculty of Agricultural Engineering
Farm Machinery and Power
IGKVV, Raipur, Chhatisgarh INDIA
rknaik1@rediffmail.com


Apoorv Prakash
M. Tech,
Department of Farm Machinery and Power Engineering,
JNKVV, Jabalpur, INDIA
apoorv_007@yahoo.com

Abstract

The planting of garlic was still not mechanized due to the lack of appropriate planting, cultivation and harvesting machinery. Hence the crop is grown in relatively small fields by using traditional methods, which, requires about 60 to 65 men-days for sowing one hectare and costing around Rs. 5,200/ ha. In this study an innovatively designed self propelled precision garlic planter capable of planting three rows of garlic cloves at a spacing of 10 × 15 cm was designed, fabricated and tested. It is developed in the workshop of Department of Farm Machinery and Power Engineering, CAE, JNKVV, Jabalpur. The theoretical seeding rate and seeding mass rate was calculated to 6,66,667 cloves/ha and 0.573 t/ha by taking crop geometry of 10 × 15 cm. Auto-CAD design and drawing was used for the fabrication of the machine. The overall length × width × height of the machine is 1,937 × 620 × 922 mm. Twelve elliptical spoons having 180 fitted in round plate of diameter 200 mm were used for metering of cloves. A 3 hp diesel engine was used as prime mover of the garlic planter. The theoretical field capacity (TFC) was calculated as 0.081ha/h, at a speed of 1.8 km/h, whereas, the actual field capacity (AFC) was found to be 0.065 ha/h with field efficiency of 79.84 %. It was observed that the placement of garlic cloves were at uniform depth under a range 4.2 cm to 5.2 cm with a minimum SD and CV of 0.33 cm and 6.92 % respectively. The miss index, multiple index and seed damage was found to be only 2.67, 8.0 and 1.46 % respectively, which was within acceptable limit. Operating cost per hour of the machine was calculated as Rs.151.00/h. For sowing one ha of land the planter required Rs. 2,321.50 /ha which was much more less as compared to manual dibbling method which required 65 man days and required additional of Rs. 2,878.00. Thus, the newly developed machine saves 55.35 % of money over traditional methods.

Introduction

Garlic (*Allium sativum L.*) is very precious spice crop having with its spices and medicinal values. India is largest producer of spice crops. The production of garlic in India is 0.677 million tonne. The farmers are generally sowing garlic by manual method, which is highly labour intensive and time consuming. It requires about 60 to 82 men-days to sow one hectare of land by maintaining row to row spacing by 15 cm and plant to plant spacing by 10 cm for better plant population. Due to high labour intensive works and higher wage rate the garlic cultivation is discouraged by farmers day by day. Though manually operated machines are fabricated but it is not so popular among the farmers due to its low field capacity. To overcome such circumstances there is an urgent need to mechanize the planting techniques for the farmers. The main objective of the study is to design and develop a self propelled garlic planter capable of singulating and planting garlic cloves at pre determined depth, row and plant spacing.

Rocha *et al*. (1991) designed and developed a manually operated planter for garlic bulbs mounted on two bicycle wheels and equipped with toothed rubber belt using the sponge teeth 25 × 47 mm and 25 mm high. In field tests using the prototype equipment, bulbs were spaced at 5 bulbs per m. Jarudchai *et al*. (2002) designed and developed a garlic planter in Thailand. This study followed research after the 3 types of garlic planter viz. (1) inclined metering plate garlic planter (2) vertical metering plate garlic planter and (3) spring plate garlic planter. The new prototype garlic planter had 12 rows and was attached to 5 HP power tiller. Masoumi (2004) developed a roller-type metering device for a laboratory prototype single row garlic planter consisting of a seed hopper, a vertical roller-type seed plate driven by an electric motor and a seed counter. Some laboratory tests were conducted to investigate the effects of roller speed and size of seed cavities (cells) on the percentage of seed singulation and cell filling performance. Maheswarr and Verma (2007) modified and evaluated a garlic planter at Etawa, UP, India. The speed of planter was 1.8 km/h, actual operating time in 24.6 minute was required to cover area of 0.01 ha with field capacity of 0.0181 ha/h and field efficiency was 78 %. Bakhtiari and Loghavi (2009) designed, fabricated and tested a tractor-mounted, ground-wheel drive, triple unit, row crop precision planter capable of planting three rows of garlic cloves on each raised bed. The results showed that the new machine was capable of planting 2, 20,000 plants ha^{-1} at the seeding depth and spacing of 12.3 and 22.7 cm, respectively. Also, miss index, multiple index and seed damage were measured as 12.23, 2.43 and 1.41 percent, respectively. Park *et al*. (2000) developed a garlic clove planter which planted garlic in upright position with its blunt root portion directed towards the ground in USA. Singh *et al*. (2006) evaluated the field performances of manually operated garlic planter at Jabalpur. The cost economics and labour requirement of the planter with the traditional method were compared. It was calculated that about 60 to 82 persons were required to sow one hectare of land because to maintain row to row spacing by 15 cm and plant to plant spacing by 7.5 cm for better plant population which costs around Rs.5658 /ha.

Material and Methods

A self propelled garlic (clove) planter was designed and fabricated at the Department of Farm Machinery and Power Engineering, College of Agricultural Engineering, JNKVV, Jabalpur. 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. The following test were conducted for design and evaluation of the garlic clove planter.

Theoretical Seeding Rate (R_{st})

The number of garlic cloves planted per hectare was calculated by using the following relationship.

$$R_{st} = 10^8 / (W \times X_s) \quad (1)$$

Where,

R_{st} = Theoretical seeding rate (seed ha^{-1});

W = Row width (cm); and

X_s = Seed spacing along the row (cm).

Seeding Mass Rate (R_{sm})

The total mass of garlic cloves planted per hectare expressed in Mg ha^{-1} was calculated by using the following relationship.

$$R_{sm} = [M / (W \times X_s)] \times 100 \quad (2)$$

Where,

R_{sm} = Seeding mass rate, (Mg ha^{-1});

M = Average mass of one seed;

W = Row width; and

X_s = Seed spacing along the row.

Miss Index (MI)

Skips or misses are created when seed cells fails to pick up and deliver seeds to the drop tubes. The missing percentage is presented by an index called the Miss Index (MI) (Bakhtiari and Loghavi, 2009) which is the percentage of spacing greater than 1.5 times the theoretical spacing. Smaller values of MI indicate better performance.

Multiple Index (DI)

Multiples are created when more than one seed is delivered by a cell. The multiples percentage is represented by an index called Multiple Index (DI) (Bakhtiari and Loghavi, 2009) which is the percentage of spacing that are less than or equal to half of the theoretical spacing. Smaller values of DI indicate better performance.

Seed Damage

In three randomly selected one kilogram samples taken from a bulk of garlic cloves passed through the metering drums and seed tubes, the number of cloves that were damaged mechanically including any significant bruising, skin removal or crushing were counted and their percentage was calculated as the seed damage percentage (Bakhtiari and Loghavi, 2009).

Coefficient of Variation (CV)

This represents the overall difference between the actual and nominal seed spacing in a percentage along a randomly selected for 5 rows of 2 m length of each planted row (Bakhtiari and Loghavi, 2009).

$$CV\,\% = \{[\sum (|D - L_1|) + |D - L_2| + \ldots |D - L_n|)] / (n \times D)\} \times 100 \quad (3)$$

Where,

D = Nominal seed spacing, mm;

L = Actual seed spacing, mm; and

n = Total number of seed spacing

measured (20).

Hoppers for Cloves and Fertilizer

Hoppers were designed to cover full width of the machine and located above the main frame. The hexagonal cross section of the seed box was usedn. The bottom was kept usually flat and rounded at the corners. A separate fertilizer box was provided and kept larger than that of seed because of higher application rates. Boxes were provided with a proper cover to avoid seepage of rain water and spilling of seed and fertilizer. The location of hopper in garlic-clove planter varied from 40 cm above the ground level. The capacity of box was determined by keeping the balance between the weight of material filled (as it affects draft) and the field efficiency of the machine. Application rates and field capacity values had to be taken into consideration.

Seed Metering Mechanism

A metering device draws seed from bulk and delivers them at the desired rates in the seed tubes for planting of garlic cloves in soil uniformly. A vertical plate cup or spoon type picking device was employed as metering mechanism in the planter. As per recommendation for clove to clove spacing i.e. 10 cm; the ground wheel of 38.18 cm diameter was used giving the circumference of 120 cm. Therefore, in one revolution the ground wheel would cover 120 cm distance dropping 12 garlic cloves.

Fertilizer Metering Mechanism

A spur gear having 12 grooves (as number of spoon on the garlic metering mechanism was 12) was selected in the present design. The orifice diameter of 12 mm was usedfor metering of fertilizer. Additional arrangement was given to calibrate the fertilizer by sliding arrangement of plates just below the hole.

Furrow Opener

The minimum clearance H_1 between the land surface and the lower edge of the frame was kept at 200 mm. **Fig 2** shows dimensions and forces acting on the furrow opener.

The height of tine (H) of furrow opener was calculated as (Varshney, *et al*., 2004):

$$H = a_{max} + H_1 + \Delta H \quad (4)$$

Where,

a_{max} = depth of tool = 11.5 cm

H_1 = length of tine = 20.0 cm

ΔH = length of tine used for fastening with frame = 4.0 cm

So, $H = 11.5 + 20.0 + 4.0$

$H = 35.5$ cm

The tine of the furrow opener was exposed first to bending due to soil resistance. The soil resistance (F_x) is horizontal and acts in the axis of symmetry of shoe. The soil resistance was assumed to be 3 to 5 times higher than actual average soil resistance (P_k) offered by the particular soil (**Fig. 1**). The value of the actual average soil resistance is obtained by the formula:

$$F_x = a \times W_w \times P_k \quad (5)$$

Where,

a = Effective working depth of tine = 5 cm

W_w = Effective working width of tine = 5 cm

P_k = Specific soil resistance for the medium soil

Specific soil resistance P_k when sowing to a depth of 15 cm under different soils is:

Light soil: 0.12 kg/cm^2

Medium soil: 0.15 kg/cm^2

Heavy soil: 0.20 kg/cm^2

Very heavy soil: 0.25 kg/cm^2

Therefore,

$F_x = 5 \times 5 \times 0.15 \times 9.81 = 36.78$ N

The soil resistance is assumed to be 3 to 5 times higher than actual average soil resistance (F_x)

Draft at the tip of tine (D_t) = 36.78 × 3 = 110.36 N

Stress (σ in Pa), causing the tine to bend was calculated as (Varshney, *et al*., 2004):

$$\sigma = \frac{6D_t\,(H_1 + a_{max})}{th^2} \times 10^4 \quad (6)$$

Where,

D_t = draft at the tip of tine, N;

t = thickness of the tine, cm and

h = width of tine, cm

It is to be assumed that the thickness (t) and width (h) of tine were 1.0 and 4.0 cm respectively. Hence,

$\sigma = 130.3 \times 10^5$ *Pa (Pascle)*

Now, Torsional stress (τ in Pa) is calculated as:

$$\tau = \frac{9D_t\,(W_w)}{8 \times ht^2} \times 10^4 \quad (7)$$

Where,

W_w = Effective working width of tine, cm; and

Thus,

$\tau = 15.5 \times 10^5$ *Pa*

Then, the reduced stress (*δ in Pa)* was calculated as:

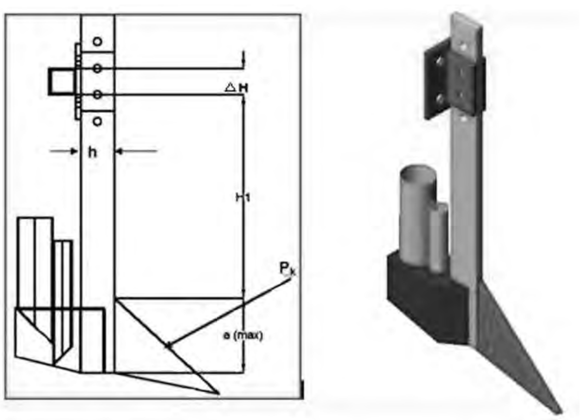
$$\delta = \sqrt{\sigma^2 + 4\tau^2} \quad (8)$$

$\delta = 10^5 \times \sqrt{(130.3)^2 + 4 \times (15.5)^2}$

$\delta = 133.93 \times 10^5$ *Pa*

The factor of safety has been taken 5 times more than that of the

Fig.1 The soil reaction and isometric view of the furrow opener



actual stress,

Therefore, the stress = $133.93 \times 10^5 \times 5 = 669.65 \times 10^5$ Pa

The allowable stress of 40C8 steel is 400 MPa (IS-5517-1993) which is more than the designed stress 1268.05. Hence, a spring steel of dimension (L × B × T) of 42.0 cm × 4.0 cm × 1.0 cm had been taken for the machine. There was a provision of 4 holes of diameter 10 mm at equal distance for lowering tine upto a depth of 8 cm.

Supporting Frame

The components of the garlic planter were mounted on the main frame (chassis) which was supported by two gauge wheels. The machine was also connected to the rigid hitch point of the prime-mover. Mostly hollow square frames made up of mild steel were used in the sowing machines. The frame was subjected to torsion and bending moment due to 3 tines arranged on one line. The material taken for the frame was of size 4 cm × 4 cm square section with thickness of material of 0.5 cm.

Depth Control-Cum-Transport Wheel

Two depth control of 25 cm diameter made out of 3.0 cm × 0.5 cm flat and 1.2 cm diameter spokes were fitted at the axle of the transport wheel. A shaft of 1.2 cm diameter supported by a square section (32 cm × 2.5 cm × 2.5 cm) attached the wheel in perpendicular direction, which was also used for lowering the machine to a proper depth as required. It can be lowered upto 8 to 12 cm as and when required.

Drive Wheel

Ground drive wheel of 38.12 cm diameter, having width 3 cm and thickness of 0.5 cm was provided below the main frame of the machine. Twelve spikes (3.7 cm × 3.0 cm × 0.5 cm) were provided on the outer periphery of the wheel to develop sufficient grip for power transmission.

Power Transmission from Ground Wheel to Metering Device

The power was transmitted through the drive wheel to the seed metering device and fertilizer metering device with the help of two set of chain and sprocket mechanism for the accurate power transmission. The power from the drive wheel drives the idler gear then transmits the power to the shaft of seed and fertilizer metering device simultaneously.

Stability of Machine

The machine was checked for stability to work in field without any up draft load to the operator. The calculation was based on simple lever formula (Kurmi, 2000) taking pivot point as traction wheel/cage wheel of the prime mover. The weight of the engine with front chassis (W_{engine}), distance between the centre of engine and pivot point (De), weight of the planter (full of fertilizer + garlic cloves) with back chassis = W_p kg, Additional weight acting towards furrow = W_{furrow}, Distance between the centre of planter and pivot point ($D_{planter}$) i.e. 93.5 cm.

So,

$(W_p - W_{furrow}) \times D_{planter} = W_{engine} \times D_e$

$W_{furrow} = 6.90$ kg

$W_{furrow} = 6.90$ which will help the machine for opening the furrow and no additional load was required to the operator. After calculations and design of each parts of garlic planter with the ergonomical and mechanical point of view the self propelled garlic clove planter was fabricated with the use of AUTO- CAD design and drawing (**Fig. 2**).

Field Test

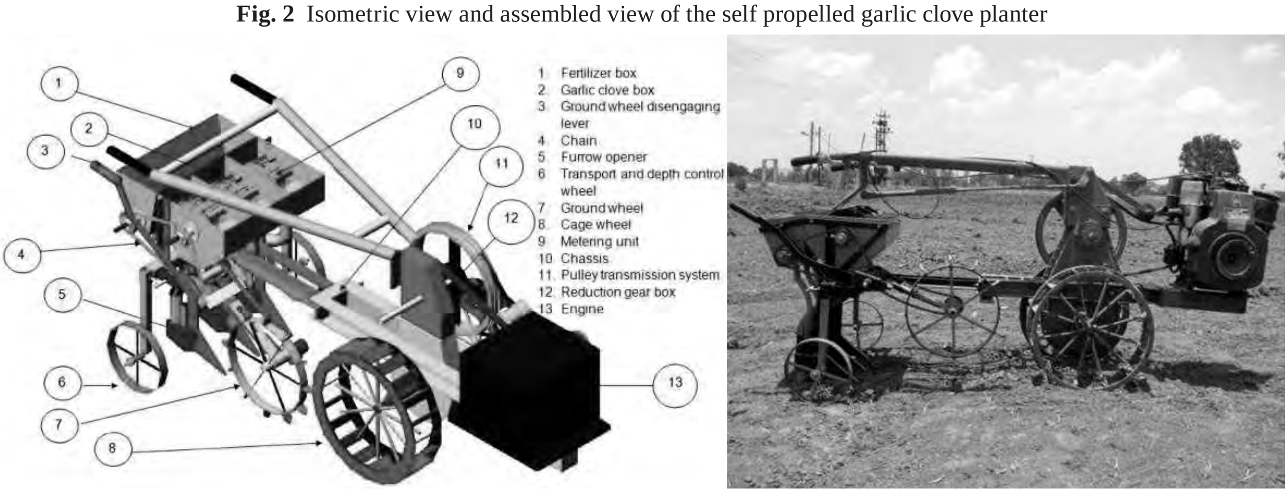
For each treatment 30 × 7 meter plot were taken in the College of Agricultural Engineering research farm. Three randomized plot were taken for three different methods of planting, i.e.

T_1: Self propelled garlic clove planter,

T_2: Manual garlic clove planter and

T_3: Manual sowing of garlic cloves by hand dibbling. The soil beds

Fig. 2 Isometric view and assembled view of the self propelled garlic clove planter



were prepared with two passes of cultivator and one pass of rotavator.

Result and Discussion

Theoretical Seeding Rate (R_{st}) and Seeding Mass Rate (R_{sm})

The number of garlic cloves planted per hectare was calculated by taking row width 15 cm and clove spacing as 10 cm to 6,66,667 cloves per ha. The total mass of garlic cloves planted per hectare expressed in Mg ha^{-1} was calculated to 0.573 M/ha by taking average mass of single clove as 0.86 g. The amount of garlic cloves planted per hectare was calculated was found to be 0.573 tonne ha^{-1} which was under acceptable limit as recommended (0.5-0.7 tonne ha^{-1}) and still saving of garlic cloves up to 22 % from traditional practices. The sample collected from the three delivery unit during calibration, were nearly same and there was very little deviation among the sample i.e. 3.96 to 5.97 g. The coefficient of variance (CV) was also very less about 1.17 % on average. Hence, it was found that the machine metered the garlic uniformly.

Field Performance of the Machine

The machine was tested in well prepared land and following data were obtained. The bulk density of soil was observed as 1.60g/cm^3 at 19.50 percent moisture content. The variety of the garlic cloves taken for study was Yamuna–Safed white. It was observed that the machine was operated at a speed of 1.8 km/h and no skidding was observed during experiment. The theoretical field capacity was calculated as 0.081 ha/h, whereas, the actual field capacity was found to be 0.065 ha/h. 20.16 percent time was loss during filling of the seed and fertilizer box, clogging of residues in boot, turning of machines and other extraneous unavoidable circumstances.

The test result shown in **Table 1** reveals the planter has effective field capacity of 0.065 ha/h with field efficiency having 79.84 %. It was also calculated that the machine required 15.47 hours to complete 1 hectare of land. The results indicated that the self propelled garlic clove planter requires only Rs.2,321.00 per ha for planting of garlic whereas, manual garlic planter and manually by hand dibbling requires Rs.3,604.00 and Rs.5,200.00 respectively.

Planting Depth of Seed/Fertilizer

It was revealed from the **Table 2** that the placement of garlic cloves were at uniform depth within a range 4.2 cm to 5.2 cm on a average of 4.79 cm with a minimum SD of 0.33 cm. The coefficient of variation was found to be 6.92 %, indicates that the cloves were placed very close to the target depth of 5 cm with an acceptable limit and uniformity. Similarly the machine was designed to place fertilizer at a depth of 10 cm. The data reveal that an average depth of 9.53 cm with minimum standard deviation of 0.67 cm (coefficient of variation 7.01 %) for fertilizer placement was achieved by this planter. It was also observed that the difference between the seed and fertilizer was within the acceptable limits of 4.75 cm on average. It increase the crop yield reduce the rotten percentage due to fertilizer contamination.

The data in **Table 2** also reveals that there was no deviation in path (along the row) due to bouncing of seed. It may be due to the placement of cloves very close to the ground surface and it was not bounce either left or right side. The range of bouncing was varies from −1.8 to 2.0 which was acceptable. Hence, the machine performance was very good in field and the placement of seed as well as fertilizer was within acceptable limit.

Miss Index (MI)

Skips or misses created when seed cell fail to pick up and deliver seeds to the drop tubes. It was observed that the percentage of spacing greater than 1.5 times the theoretical spacing. In present study smaller values of the miss index i.e. 2.67 % indicate better performance of the machine, which was under acceptable limit. These missing were perhaps due to the jerk or vibration which produced empty spoons during operation. It also may be due to the clogging/segregation motion of cloves along the crop tubes for a

Table 1 Comparison of different method of planting of garlic cloves

Method of planting	AFC, ha/h	Labour required	Cost, Rs	
			Per h	Per ha
Self propelled garlic planter	0.065	2 men	150.90	2321.00
Manual garlic planter (without fertilizer application)	0.015	2 men + 3 men	24.06 + 30.00 = 54.06	3604.00
Manual by hand dibbling	0.0019	65 men days	10.00	5200.00

Table 2 Uniformity of placement of seed and fertilizer

S No.	Seed placement depth, cm	Fertilizer placement depth, cm	Average distance between seed and fertilizer, cm	Seed bouncing (left − ve and right + ve), cm
Mean	4.79	9.53	4.75	0.28
SD	0.33	0.67	0.55	1.21
Range	4.2-5.2	8-10.5	3.7-5.5	−1.8 to 2.0
CV	6.92	7.01	11.55	439.01

little time.

Multiple Index (DI)

Multiples were created when more than one seed is delivered by a spoon. The seed fall at a distance of ≤ 5 cm indicate one multiple as clove to clove distance is found to be less than the theoretical spacing of the cloves. The average multiple index for the data taken along the planted rows was found to be 8 percent. The level of multiple index is considered to be low and acceptable as it doesn't affect the yield. The multiple index may be due to the small size of cloves, as compare to the spoon designed. Overall the data indicates that the machine performance was better if graded seed of bold quality were used by farmer.

Coefficient of Variation

The overall differences between the actual and theoretical seed spacing along a randomly selected 2 m length was calculated. It was observed that the seeds were placed on average of 10.12 cm distance, which was much closer to the designed spacing with SD 1.56 and coefficient of variation of 15.36 %.

Seed Damage

The average percent of garlic clove damage were calculated by collecting seeds along the rows for a span of 15 m randomly. The number of cloves that were damaged mechanically including any significant bruising, skin removal or crushing was observed only 1.46 percent which was considered to be very low and within acceptable limit.

Cost Economics

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.

It was found that cost of operation of the machine mainly depends upon its annual use. In present assumption of 200 h use annually, the fixed cost was found to be Rs. 91.00 whereas, operational cost as Rs.60.00. Including both fixed and operational cost the machinery cost per hour was Rs.151.00/h. For sowing one ha of land the planter required Rs.2,321.50/ha which was less compared to manual dibbling method which required 65 man days and required additional of Rs.2,878.00. Thus the newly developed machine would save 55.35 % of money over traditional methods.

Conclusions

The actual field capacity (AFC) was found to be 0.065 ha/h with field efficiency of 79.84 %. It was observed that the placement of garlic cloves were at uniform depth under a range 4.2 cm to 5.2 cm with a minimum SD and CV of 0.33 cm and 6.92 % respectively. The miss index, multiple index and seed damage was found to be only 2.67, 8.0 and 1.46 % respectively, which was within acceptable limits. The machinery cost per hour was calculated as Rs.151.00 /h. For sowing one ha of land the planter required Rs.2321.50 /ha which would save 55.35 % of money over traditional methods.

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■■

Drying of Dates Using Multiple Collectors Areas Followed by Equal Drying Areas in a Solar Tunnel Dryer

by
M. A. Basunia H. H. Al-Handali M. I. Al-Balushi
Department of Soils, Water and Agricultural Engineering, CAMS, Sultan Qaboos University, P.O. Box 34, Al-Khod123, Muscat, Sultanate, OMAN
basunia@squ.edu.om

Abstract

A 12 meter long and 2 meter wide tunnel was designed and constructed to analysis the performance of a solar tunnel dryer using multiple drying and collector sections instead of continuous single collector section followed by a single continuous drying section. The area of each solar collector section was 2 × 2 m followed by an equal drying area. Thus there were three drying zones and three collector zones over the entire tunnel base. The drying air was forced from the collector regions (north side) to the drying regions (south side) of the half circled tunnel where the product was dried. The drying temperature could be easily raised by some 5-30 ºC above the ambient temperature inside the tunnel at an air velocity of approximately 0.25 m/s. The test was conducted with 136.0 kg freshly harvested dates with initial moisture content of 39.98 % (wet-basis). The dates were dried to a final moisture content of 16.80 % (wet-basis) within a day (12 hours). The results indicated that the drying was faster in the multiple collectors zones arrangement followed by equal multiple drying zones than the single continuous collector zone followed by single continuous drying zone. It was possible to reach the moisture content level for safe storage within a day (12 hrs) with multiple collectors and drying areas whereas it required two days (20 hrs) in a single continuous collector and drying areas. The improvement in the quality of dates in terms of color, brightness, flavor, and taste and food value was distinctly recognized than the open air natural drying method.

Keywords drying, dates, multiple collector zones, multiple drying zones, solar tunnel dryer, moisture content.

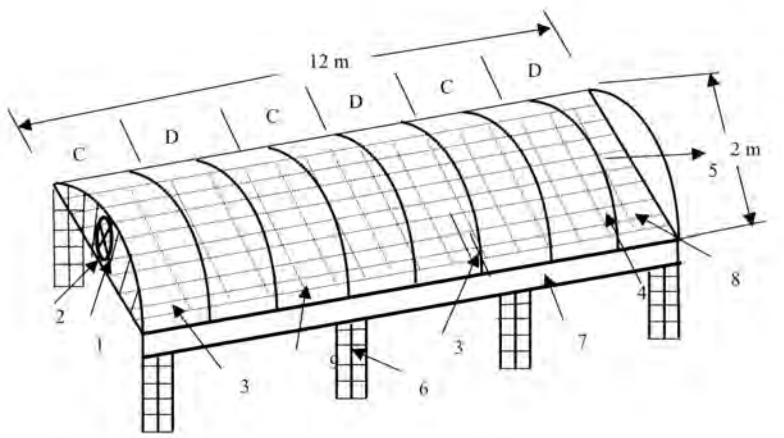
Introduction

Demand of dried food products is increasing because dried foods are tasty, nutritious, lightweight, easy-to-prepare, easy-to-store and use, and the energy input is less than what is needed to freeze or can. Also the storage space is minimal compared with that needed for canning jars and freezer containers. So the drying is an important operation in agriculture because it is the cheapest, easiest and most common method of preserving and storing of perishable agricultural products. Solar energy is a renewable resource, non-polluting and friendly to the environment. Today rising oil prices is a major frustration on many government as well as individual levels. The use of solar thermal systems in drying is practical, economical and the responsible approach. The availability of good information is lacking in many parts of the world where solar food processing systems are most needed.

There are various methods and techniques available to dry fruits, grain and other agricultural products. Each method has its own advantages and limitations.

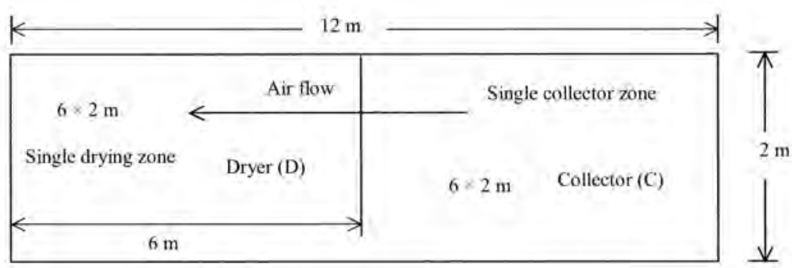
Annual production of dates in Oman is estimated about 200,000 tones (Ampratwum, 2003). Freshly harvested dates with high moisture content must be dried to preserve them unless they are to be consumed within a few hours of harvesting or placed in low temperature storage. Most of the dates are still dried by traditional method of open air natural sun drying in Oman. This method of drying normally takes 14 to 21 days (Ampratwum, 2003). The traditional open air natural sun drying methods often yield poor quality. In most cases the drying yard is not properly fenced. So the product is not protected against dust, rain and wind, or even against insects, birds, rodents and domestic animals while drying. Soiling, contamination with microorganisms and infection with disease-causing germs are taking place during drying by these methods. Dew may accumulate on the surface of the dates and causes mold growth if the date is not covered properly at night. Color change occurs and drying becomes slow (Ahmed and Mirani, 2008). The quality of dried dates is likely to be varied by partial over drying and possible contamination by dust, sand and insects infestation. The solar drying system provides higher temperature compared to open air natural sun drying, and the temperature in solar drying system is controllable. In general, the dates producing countries receive a high amount of solar radiation. The solar drying facilities combine the advantages of traditional and industrial methods, namely low investment costs and high product quality.

Fig. 1 A rough sketch of a solar tunnel dryer used in this study

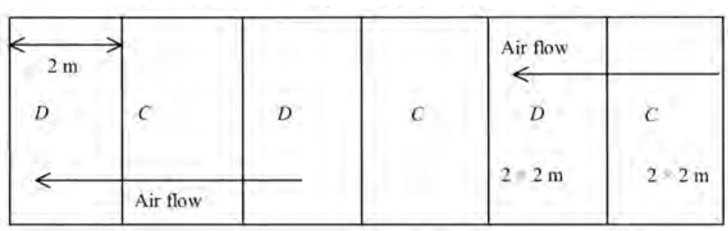


1. Air inlet to the tunnel, 2. AC fan, 3. Light-weight metallic net, 4. Dryer section (Ds), 5. Air outlet from the dryer, 6. Bricks supports, 7. Wooden frame to support aluminium bends; 8. Wire mesh net over wooden base in dryer parts only (not visible), 9. Absorber plates (black plastic board, not visible, Cs).

Fig. 2 Arrangement of dryer and collector zones over the almost airtight base of the tunnel (C = collector zones, D = drying zones)



(a) Single collector zone followed by a single collector zone



(b) Arrangement of multiple collector and drying zones

Ampratwum (2003) reported the construction procedures and test results of a natural convection solar dates dryer in Oman, but due to lower drying rates and capacity, it did not gain popularity. A successful new solar tunnel dryer was designed and developed at the University of Hohenheim, Germany, to meet the drying requirements of small farmer cooperatives (Lutz *et al*., 1987; Esper *et al*., 1994, 1996). This dryer is classified as a solar dryer that have been successfully tested under field conditions in about 30 countries under different climatic conditions in drying various agricultural products (Schrimer *et al*., 1996; Mastekbayeva *et al*., 1998; Bala and Mondal, 2001; Basunia and Abe 2001a, 2001b, Basunia *et al*,. 2009; EI-Sebii *et al*., 2002; Bala *et al*., 2003). Unfortunately, solar tunnel dryer has not yet been established for drying dates in Oman where solar energy is abundant and can be used for drying of dates and other agricultural products. Basunia *et al.* (2009) reported the performance of a solar tunnel dryer in drying dates using single continuous collector and drying areas. This study was conducted to analyze the performance of the solar tunnel dryer using multiple collector areas followed by equal drying areas at the Department of Soils, Water and Agricultural Engineering, Sultan Qaboos University, Oman.

Materials and Methods

The prototype solar tunnel dryer consists of multiple flat plate air heating solar collectors and drying areas, fabricated as a single unit (**Fig. 1**). The tunnel is 2.0 m wide and having a length of 12 m. The light-weight aluminum frames were used as the upper structure for the entire tunnel to support the transparent plastic cover. The tunnel was placed on concrete block substructures 500 mm above the ground surface. The ply wood planks (0.9 × 2.0 m) of thickness 4 mm were used as the bed for the entire tunnel to make the base of the tunnel almost air tight. The air tight base of the tunnel was divided into six equal zones (three drying and three collectors) each having an area of 3 × 2 m (**Fig. 2**). Over the wooden base, black painted metallic sheets of thickness 0.25 mm were used as the absorber plate in the collector sections of the tunnel. They were arranged in such a way that each collector zone was followed by a drying zone starting with collector zone from the north side of the tunnel. Thus there were three drying zones and three collector zones over the entire tunnel base (**Fig. 2**). This arrangement helped to expose the whole product to almost same temperature instead of exposing the product to variable temperatures as in a continuous single collector zone followed by a single drying zone. The steel wire mesh nets were spread over the drying zones to dry the desired product. A 0.2 mm thick UV stabilized colorless polyethylene sheet was used as the transparent cover over the entire tunnel. The entire tunnel became almost air-tight except the inlet opening (north side) for fixing a fan and the exit side (south side) for the moist air. The light weight (30 × 1 mm) aluminum flat bars were cut into pieces of each having a length 3.14 m. These pieces were bent into half-circles before fixing with the wooden base of the tunnel. Two solar powered fans (40 W) one at each side of the tunnel were used to force the drying air to flow over the product and passed through the exit. The fans were installed at the holes made on the wooden cover plat, 150 mm above the base of the tunnel. Thus the drying air was forced from the collector regions to the dryer regions where the product is to be dried. The fan has an air handling capacity of 7.3 m^3/min against a maximum static pressure of 157 Pa (16 mm H_2O). Prior to the operation of the dryer thermocouples were installed to record the temperatures at different locations within the tunnel. Nine thermocouples were connected within the tunnel; three at each of the mid-points of the collector zone at the air entrance side, dryer zone at exit and as well as the whole tunnel. The moisture content of whole dates was determined by using oven drying method. The sample of whole dates was kept at 100 ºC for 20 hours (AOAC, 1984).

Results and Discussion

No-Load Tests (Test Without Product)

The no-load tests with and without fan were conducted to detrmine the thermal characteristics of the whole tunnel at different weather conditions and also, the temperature gradient both in the collector and dryer regions of the tunnel. **Fig. 3** shows the variations of ambient, collector and dryer temperatures with time of the day. The drying air temperature could be easily raised by some 5-30 ºC above the ambient temperature at an air flow rate of 0.15-0.25 m/sec. The difference between the drying air temperature and ambient temperature gradually increased from morning till mid-day then gradually decreased in the afternoon (**Fig. 3**). The highest temperature 69 ºC was observed at around 1 PM. This indicated that solar tunnel dryer can be easily used to dry dates. In no load tests the maximum difference between the average temperatures of the dryer and collector parts was

Fig. 3 Variations of ambient, dryer and collector air temperatures with time of the day (August 8-9, 2008) under no load condition

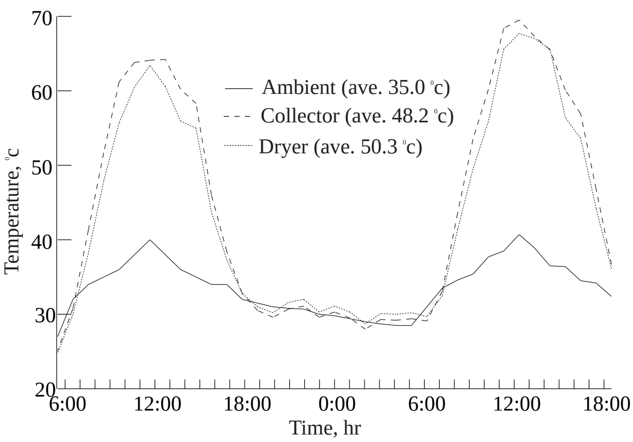
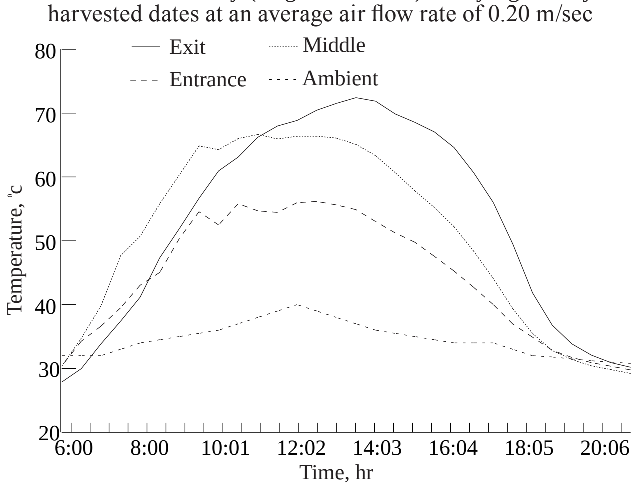


Fig. 4 Variations of ambient, dryer and collector temperatures with time of the day (August 10, 2009) in drying freshly harvested dates at an average air flow rate of 0.20 m/sec



about 2 ºC. This indicated the uniformity of temperatures inside the entire tunnel except at entrance side of the collector.

There was almost no temperature gradient found in the vertical and horizontal directions of the whole tunnel. A no-load test was conducted without using fan. It was observed that the highest temperature inside the tunnel reached 75 ºC when the fan was not in operation. The difference between the average temperatures inside the tunnel without and with fan was about 10 ºC. This indicated the operation of the dryer without fan would cause over drying of the product particular during 11:00 AM-3:00 PM. The average solar irradiance was about 500 w/m^2.

Test with Freshly Harvested Dates

The full load test with 136.0 kg freshly harvested dates (khalas variety) was conducted to study the dryer performance on August 10, 2009. The average initial moisture content of the freshly harvested dates collected from the Agricultural Farm of the University was 39.98 % (wet-basis). The dates were spread on three drying zones of the tunnel in a single layer thickness. The drying was started at 6:30 AM and continued till 6:30 PM. The approximate sun rising and setting time was 6:00 AM and 7:00 PM, respectively. The moisture content was reduced to 16.80 % from initial 39.98 % wet-basis within 12 hours. Samples were collected for moisture content determination at the end of drying period. The final moisture content at the end of one day drying was found 16.80 % (wet-basis).

The variations of the tunnel exit (dryer exit), tunnel inlet (collector entrance) and ambient air temperatures with drying time (6:00-19:00 hr/day) have shown in **Fig. 4**. The variations of the solar radiation with drying time are shown **Fig. 5**. The average drying air and ambient temperatures were 52.0 ºC and 36.20C, respectively, and the average total radiation on a horizontal surface was 589.2 w/m^2. The average temperature in the collector part was lower than the average temperature in the dryer part because of the presence fan at the air entrance side of the collector.

To compare the drying rates of the solar tunnel dryer and the natural convection open air sun drying, a separate tests was conducted with about 100 gm samples under the same weather conditions. The samples from the solar tunnel dryer and the open air natural sun drying were taken at one to three hour intervals of drying starting from 6:30 AM and continued till 6:30 PM on each day. The moisture removal rate was much high in solar tunnel dryer than the open air natural sun drying method (**Fig. 6**). It took only one day (12 hours) to reduce the moisture content to safe storage level (16.80 %) in solar tunnel drying system, whereas it was reduced to 30.5 % (w.b.) only in the same time in natural open air sun drying method. It was considered that there was no moisture addition to or subtraction from the products during the overnight as the products were covered by plastic sheets. It took almost seven days to reduce the moisture level to 16.8 % (w.b.) in natural open air sun drying method.

Conclusions

This paper describes the design, construction and experimental investigation of a solar tunnel dryer with multiple collector zones followed by equal drying zones over the air tight base of a tunnel. The no-load tests clearly indicated that the drying temperature could be easily raised to some 5-30 ºC above the ambient temperature while the average air flow velocity inside the tunnel was 0.15-0.25 m/s. The aver-

Fig. 5 Variations of solar radiations in drying dates on August 10, 2009 from morning to evening

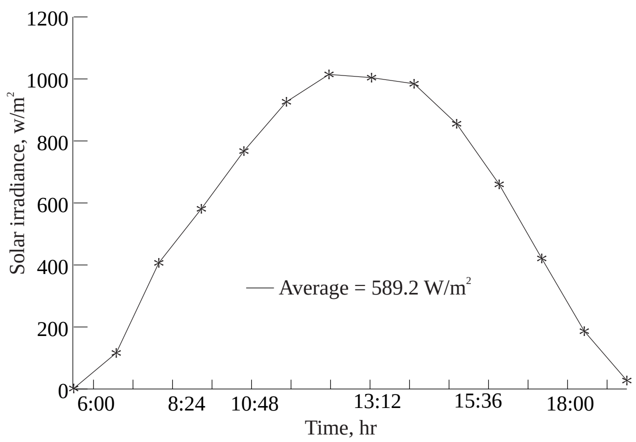
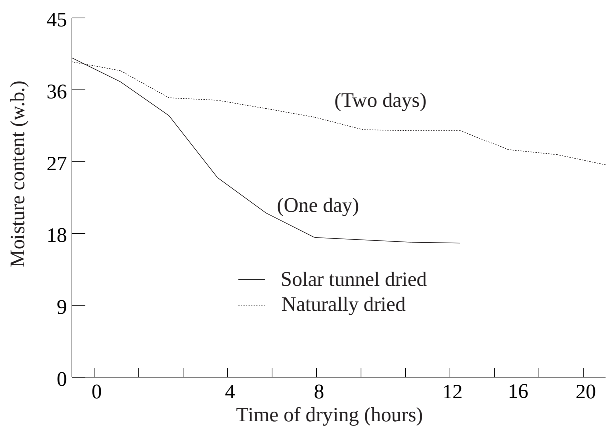


Fig. 6 Variations of moisture contents in solar tunnel drying and natural open air sun drying methods with drying time,



age drying air temperature inside the tunnel could be easily attained 45-55 ºC. The experiment was carried out with 136 kg freshly harvested dates and the performance of the solar tunnel dryer was compared to single and continuous collector followed by a single continuous drying area over the tunnel base. A considerable reduction in drying time was obtained using multiple collector areas instead of a single collector area. It was possible to reduce the moisture content level to safe storage (16.80 % w.b.) within one day (12 hours) with multiple collectors, whereas it took two days (20 hours) in single collector. The comparison also showed that drying in solar tunnel dryer was much faster than the natural convection open air natural sun drying both in single and multiple collectors. These investigations show that solar tunnel dryer can be used for low temperature drying of dates and other agricultural products in the rural areas of Oman where electricity is not available.

Acknowledgement

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EVENT CALENDAR

◆ ADAGENG 2014
—12th International congress on mechanization & Energy in Agriculture—
June 3–6, 2014, Cappadocia, TURKIYE
http://www.adageng2014.com

◆ DLG-Feldtage 2014
—One of the largest agricultural machinery exhibition in Germany—
June 17-19, 2014, Hannover, GERMANY
http://www.dlg-feldtage.de/en.html

◆ First International Field Days for crop production and agriculture machinery
July 2–4, 2014, Volga Region, RUSSIAN
http://www.dlg.org/news_agriculture_pl.html?detail/dlg.org/1/2/6256

◆ AgEng 2014 Zurich
—Engineering for improving resource efficiency—
July 6–10, 2014, Zurich, SWITZERLAND
http://www.AgEng2014.ch

◆ Canadian Society of Biosystems Engineers CSBE
—Joint International Meeting with ASABE—
July 12-16, 2014, Montreal, CANADA
www.asabemeetings.org/
Conference 2014 The 5th International Workshop:
—Applications of Computer Image Analysis and Spectroscopy in Agriculture—

The CIGR Working Group on Image Analysis for Agricultural Products and Processes is organizing the conference to increase the collaboration between institutions, academia, government, industry and individuals in the field of computer vision and image analysis for food and agriculture.

The conference is open to all researchers interested in optical systems for agricultural products and processes.

http://www.asabe.org/meetings-events/2014/07/2014-applications-of-computer-image-analysis-and-spectroscopy-in-agriculture.aspx

◆ 2014 International Symposium on Flexible Automation (ISFA 2014)
July 14–16, 2014, Hyogo-ken, JAPAN
http://www-dsc.mech.eng.osaka-u.ac.jp/ISFA2014/

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

◆ 18th World Congress of CIGR
—International Commission of Agricultural and Biosystems Engineering & CIGR Section III ATOE (Automation Technology for Off-road Equipment) Conference—
September 16-19, 2014, Beijing, CHINA
http://www.cigr2014.org

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

◆ XI Latin American and Caribbean Congress of Agricultural Engineering 2014
October 6-10, 2014, Cancun, MEXICO

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

http://chapingo.mx/dima/clia2014/

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

◆ XXXVI CIOSTA CIGR V Conference 2015
—Environmently Friendly Agriculture and Forestry for Future Generations—
May 26-28t, 2015, Saint-Petersburg, RUSSIA

CIOSTA- Commission Internationale del' Organization Scientifique du Travail en Agriculture was founded in 1950 and has organized many conferences, seminars, workshops and other meetings on the optimization of bio-production management and work, system engineering and innovative technologies. The theme of the Conference 2015 is "Environmentally Friendly Agriculture and Forestry for Future Generations" and is now calling for papers.

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

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.

1143

Studies on Environmental Parameters, Energy Requirement and Techno-Economics of Capsicum Grown under Greenhouse: **J. C. Paul,** Associate Professor, College of Agricultural Engineering and Technology, Orissa University of Agriculture and Technology, Bhubaneswar -751 003, INDIA; **J. N. Mishra,** Associate Professor, same; **P. L. Pradhan,** Associate Professor, same.

An experiment was conducted during winter 2007-08 in a semi-cylindrical greenhouse of size 4 m × 25 m for cultivation of capsicum at Bhubaneswar in coastal Orissa, India. Greenhouse was effective in raising the temperature during cold night period inside the greenhouse thereby creating a better microclimate for production of higher yield and quality fruits than open field cultivation. The growth and yield of capsicum was better under greenhouse than open field cultivation. The yield of capsicum per sq. m. inside the greenhouse was 2.17 times more over open field condition. The study indicates that the input energy per unit of capsicum produce is 3.38 MJ/kg under open field condition and 4.1 MJ/kg under greenhouse cultivation. The higher energy requirement for greenhouse cultivation is mainly due to the framed structure and the glazing materials used in the greenhouse. The assessment of input energy establishes the priorities for input energy optimization. The greenhouse was evaluated in terms of its techno-economic analysis, which was carried out by using different economic indicators such as Net Present Value, Benefit Cost Ratio, Internal Rate of Return and Pay Back Period and compared with open field cultivation. The net present value of investment made on greenhouse for cultivation of capsicum was Rs.119,110 as compared to Rs.43,239 when grown in the open field. The benefit cost ratio for greenhouse was 2.61 and 2.58 for open field cultivation. The internal rate of return for greenhouse was 40 and 35 percent for open field cultivation. The pay back period for capsicum under greenhouse was 4 years. It was observed that, techno-economically; cultivation of capsicum in winter under greenhouse will be acceptable by the farmers of Orissa.

1215

Preparation of Barley Chips and its Packaging and Storage

Jyoti Prakash, Department of Post Harvest Technology, Sher-e-Kashmir University of Agricultural Sciences and Technology, Kashmir, Jammu and Kashmir, INDIA; **H. R. Naik**, same; **Syed Zameer Hussaina**, same, zameerskuastj@rediffmail.com; **Baljit Singh**, Department of Food Science and Technology, Punjab Agricultural University, Ludhiana

The aim of the present study was to evaluate the effect of salt concentration and packaging materials on the quality characteristics of barley chips during the storage under ambient conditions. An increase in moisture content, total sugars and amylose was observed during 180 days of storage period and the increase was found more in chips packed in polyethylene packages. However, a decreasing trend was observed in ash content, fat, protein, starch, dietary fibre and in amylopectin content during the storage and the decrease was observed more in chips packed in polythene packages. Further, the colour difference (ΔE) and the crispness in chips was found to be decreasing during the storage. With the increase in salt concentration (1 and 2 percent) moisture content and ash content of chips was found to be increased, while as fat content and crispness decreased. The overall acceptability score decreased significantly during the storage (3.77 to 3.08). The chips with 2 percent salt and packed in aluminum based laminates obtained high mean score. Among the different formulations T_2 (2 percent salt, polyethylene) recorded lowest breakeven point (24.03 kg) and highest margin of safety (125.97 kg), whereas T_3 (1 percent salt, laminate) recorded highest breakeven point (28.94 kg) and lowest margin of safety (121.06 kg).

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.

1217

Effect of Spade Angle and Spading Frequency of Spading Machine on Specific Soil Resistance and Pulverization

Ritu Dogra, Associate Professor, Dept. of Farm Machinery & Power Engineering, Punjab Agricultural University, Ludhiana (Pb) –141004, ritudogra@pau.edu; **Baldev Dogra**, Research Engineer, same, brhdogra@gmail.com; **Pawan Kumar Gupta**, Prof. & Dean (Retired), College of Agricultural Engineering & Technology, same; **BD Sharma**, Professor, Dept. of Soils, same

The effect of spade angle and spading frequency on various dependent variables, i.e. specific soil resistance encountered, energy consumed per unit volume of soil moved, weighted mean clod size, soil bulk density, soil cone index and cone index ratio were studied. The experiments were conducted in soil having 15.7 % clay, 53.6 % silt, and 30.7% sand. During experimentation, moisture content of soil was maintained between 13 and 14 %. The spade angles used were A1 (straight), A_2 (15º) and A_3 (30º). Four levels of bite lengths viz. 4, 6, 8 & 10 cm at travel speed of 18.47 cm/sec were selected for the study. These corresponded to four levels of spading frequencies namely F_1 (1.85 cycles/s), F_2 (2.31 cycles/s), F_3 (3.08 cycles/s) and F_4 (4.62 cycles/s). The spading frequency was determined by dividing the travel speed by the bite length. The dependent variables decreased with increase in spade angle and spading frequency. However, the cone index ratio increased with increase in spade angle and spading frequency. Therefore, for maximum pulverization and optimal specific soil resistance and energy consumption, larger spade angle and higher spading frequency were considered to be desirable.

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NEWS

Congratulations!

◆ 100th Publication of CIGR Newsletter

CIGR's quarterly *newsletter* published its 100th issue in December 2013. CIGR started publishing its newsletter about 30 years ago and has offered information on member associations, members, sections, working groups and future events via post and its website. This year CIGR will change its publication from paper to electronic format and will be available immediately to people all over the world.

Please see further information at http://www.cigr.org/

◆ Dr. Mohammad Ali Basunia won the KIDPA-2014 in Best New Technique

Dr. Mohammad Ali Basunia (co-editor of AMA representing Oman, Assistant Professor at Sultan Qaboos University, Sultanate of Oman) won the KIDPA (Khalifa International Date Palm Award)-2014 in Best New Technique (2nd winner) to develop solar date dryer at Sultan Qaboos University, Oman. The KIDPA was established under the patronage of His Highness Sheikh Khalifa Bin Zayed Al Nahyan, President of the UAE as the date palm has long been an important part of the lives in the region. This award has been set up as a platform to recognize and reward individuals and institutions all around the world who have contributed significantly to the dates palm field.

The prize is 200,000 UAE Dirham (≈ 55,000 USD) in addition to an official certificate and a crest. This prize was given in Emirate Palace Hotel, Abu Dhabi, United Arab Emirate on March 16, 2014.

■■

NEW BOOK

LAUNCHED E-COURSES FOR AGRICULTURAL ENGINEERING

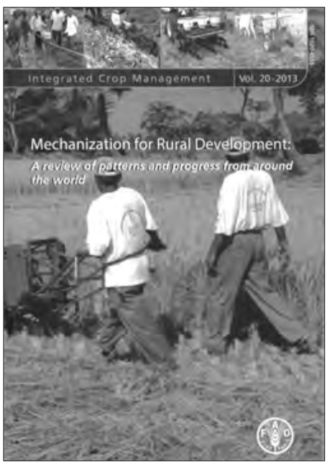
"e-Courses for Bachelor of Tech. (Agricultural Engineering)"

on moodle platform delivered on-line & off-line

by National Agricultural Innovation Project, Indian Council of Agricultural Research

The classes on Agricultural Engineering are offered online and offline in India. This course was developed by Anand Agricultural University, Indian Institute of Technology Kharagpur, Punjab Agricultural University, and Tamil Nadu Agricultural University. The course comes with 4 CDs; the topics are dairy & food engineering, workshop technology, soil & water conservation engineering and applied electronics and instrumentation. It provides easier and accessible study opportunities.

For more details, Indian Council of Agricultural Research
http://www.icar.org.in/en



FAO'S PUBLICATION IN 2013
Integrated Crop Management Vol. 20-2013

"Mechanization for Rural Development"

—A review of patterns and progress from around the world: Plant Production and Protection Division—

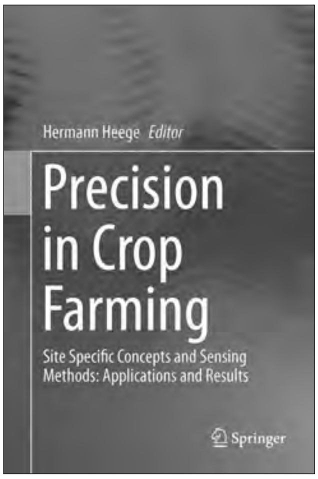
This publication presents a kaleidoscopic view of agricultural mechanization experiences from all over the world and provides its issues for third world countries focusing on many specific sites/ regions to promote sustainable mechanization technologies.

The list of the chapters is as follows:

[Africa] **1.** Investing in Agricultural Mechanization for Development in East Africa/ **2.** Agricultural Mechanization in Southern African Countries/ **3.** Agricultural Mechanization in West and Central Africa **[Asia**] **4.** Rural and Agricultural Mechanization in Bangladesh and Nepal: Status, processes and outcomes/ **5.** Agricultural Mechanization in India (Gajendra Singh)/ **6.** China Development of Farm Mechanization and the Agricultural Machinery Industry (Maohua Wang) **[Near East**] **7.** The Near East Region (Bassam A Snobar and El Hassane Bourarach) **[South America**] **8.** The Development of Farm Mechanization in Brazil **[Transition Countries of Eastern Europe and Asia**] **9.** Agricultural Mechanization in Countries in Transition in Eastern Europe and Central Asia **[Cross-cutting themes**] **10.** Agricultural Mechanization and the Environment/ **11.** Agricultural Mechanization Strategies (John Ashburner and Reynaldo Lantin)/ **12.** Agricultural mechanization in development: A donor's view (Tokida Kunihiro) **[Integrated Crop Management**] **13.** Off-farm use of agricultural machinery/ **14.** Agricultural Machinery Manufacturing and Supply **[Information Exchange**] **15.** Investing in Information Dissemination and Exchange/ **16.** Information Exchange and Networking: the RNAM Experience (Reynaldo Lantin)

For more details, FAO (Food and Agriculture Organization of the United Nations)
http://www.fao.org//home/en/

NEW BOOK



Precision in Crop Farming

Site Specific Concepts and Sensing Methods: Applications and Results
Heege, Hermann J. University of Kiel, Kiel, Germany (Ed.)

About this book

● Interdisciplinary approach that pervades all chapters
● The concept to deal with complicated topics simply

High yields and environmental control in crop farming require thorough study of the local growing conditions. Large machines are useful for some large fields but may not be efficient for other fields. Also, because of the recent advances in agricultural mechanization, some farmers feel the loss of the immediate and close contact with soils and crops.

The modern advanced technology, proximal sensing and signals from satellites can solve this deficit because it can adjust farming operations of small to large fractions. This can be used in various areas such as soil cultivation, sowing, fertilizing and plant protection.

This book offers the ideas of effective crop farming for Japanese agricultural engineers, too.

Popular Content within this Publication

Introduction: Heege, Hermann J./ Site-Specific Soil Cultivation: Heege, Hermann J./ Site-Specific Weed Control: Gerhards, Roland/ Heterogeneity in Fields: Basics of Analyses: Heege, Hermann J./ Site-Specific Sowing: Heege, Hermann J.

CONFERENCE MINUTES PRINTED

"48th Annual Convention of Indian Society of Agricultural Engineers (ISAE) and Symposium on Engineering Interventions in Conservation Agriculture"

—Organized by ISAE and College of Technology and Engineering, Maharana Pratap University of Agriculture & Technology—

The ISAE celebrated its 50th anniversary this year and had 48th Annual Convention from February 21- 23 in Udaipur, India. The convention was attended by agricultural engineers not only from India but also from several countries such as USA, Canada, Thailand, and Japan. It provided an opportunity for learning and interaction among them sharing the common interest in the development of the third world countries.

Some of abstracts of the papers on the convention

[Energy in Agriculture and Other Areas] i. Biomass Conversion Technology/ **ii.** Other Renewable Energy Technology **[Farm Power & Machinery] i.** Tillage, Tractor and Agri Mechanization/ **ii.** Sowing Planting, Intercultural and Plant Protection Equipment. **iii.** Harvesting Threshing Ergonomics Agri Machinery **[Soil and Water Engineering] i.** Application of Remote Sensing & GIS in Agriculture/ **ii.** Use of Mathematical Simulation Models in Agriculture/ **iii.** Micro Irrigation System/ **iv.** Climate Change and its Effect on Water Resources/ **v.** Conservation Agriculture and on Farm Water Management/ vi. Artificial Groundwater Recharge and Watershed Management

For more information, ISAE (New Delhi)
http://www.isae.in

New Co-operating Editors

Kamaruddin Abdullah

- **Nationality:** Indonesia
- **Present Post:** Director at Darma Persada University Postgraduate School
- **Qualifications:** 1976 Ph.D.(Ag.Eng.) University of Tokyo
- **Education:** 1976 Ph.D at Tokyo University of Agriculture and Technology in Indonesia
- **Experiences:**
  2007-2011 President of Darma Persada University Postgraduate School
  1977-2007 Lecturer/ Researcher at the Agricultural Engineering Department of Bogor Agricultural University
- **Awards:**
  2008 & 2009 The best 100 and 101 Indonesian developers on solar drying
  2008 CAFEO honorary fellow
  2002 CIGR fellow
  2001 Kishida International Award
- **Publications:** H.T and Kamaruddin Abdullah, 2010. Energy Analysis On Simultaneous Charging And Discharging Of Solar Thermal Storage For Drying Application, Drying Technology, International Journal, Vol.28 No.9. among others

---

Brian G. Sims

- **Nationality:** UK
- **Present Post:** FAO Agricultural Mechanization Consultant.
- **Education:** 1972 MSc (Agricultural Engineering) at University of Reading and National College of Agricultural Engineering, Silsoe, UK
- **Experiences:**
  2003-present the Food and Agriculture Organization of United Nations
  Leader of the International Development Group at Silsoe Research Institute
  2002 Received AMA Kishida International Award
  1985 Invited as a visiting researcher at Stanford University
- **Publications:**
  Technical Editor of Agriculture for Development (Ag4Dev) the Journal of TAA among others
- **Website:** www.engineering4development.co.uk

Oyelade Opeyemi Adeniyi

- **Nationality:** Nigeria
- **Present post:** Obtaining Doctor of Philosophy in Agricultural and Biosystems Engineering at University of Ilorin, Ilorin, Kwara State, Nigeria
- **Education:** 2011 Master of Engineering (M. Eng.) in Agricultural Engineering at University of Ilorin, Ilorin, Kwara State, Nigeria
- **Experiences:**
  2002-present Department of Farm Power & Machinery; National Centre for Agricultural Mechanization (NCAM)
  2001-2002 Development Finance Office, Central Bank of Nigeria (CBN), Abeokuta Branch
- **Publications:** K. C. Oni and O. A. Oyelade (2014): Mechanization of Cassava for Value Addition and Wealth Creation by the Rural Poor of Nigeria. AMA. 45 (1): 66-78. among others
- **Membership to Prefessional Societies:** Member of the Nigerian Institution of Agricultural Engineers (NIAE) in 2004/ Member of the International Soil Tillage Research Organization (ISTRO) in 2007/ -Engineering Registered by the Council for the Regulation of Engineering in Nigeria (COREN) in 2008

Co-operating Editors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A A K El Behery


R J Bani


I K Djokoto


D K Some


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J C Igbeka


E U-Odigboh


K C Oni


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A H Abdoun


A B Saeed


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M Z Bardaie


M P Pariyar


M A Basunia


A D Chaudhry


A Q Mughal


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Retirement Co-editors` Name List

Co-editor`s name	Nationality	Inaugural year	Retired year
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Manbahadur Gurung	Bhutan	1972	2006
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Giuseppe Pellizzi	Italy	1973	2012
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Bilash Kanti Bala	Bangladesh	1976	1982
George B. Hanna	Egypt	1976	1988
Siswadhi Soepardjo	Indonesia	1976	1985
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Arumugam Kandiah	Ethiopia	1978	1989
Bherulal T. Devrajani	Pakistan	1978	2004
Satish Chandra	Fiji	1979	1990
Jitendra P. Mittal	Nigeria	1980	1993
Naresh Chandra Saxena	India	1980	1988
Paris Andereou	Lebanon	1980	1984
Wang Wanjun	China	1980	2012
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Julien G. Van Lancker	Brundi	1981	1989
Suppiah Kathirkamathamby	Sri Lanka	1981	1991
Armed Hossain Mirdha	Mexico	1982	1991
A. A. Valenzuela	Chile	1982	2013
David Boakye Ampratwum	Ghana	1982	2011
John Kilgour	U. K.	1978	2014
Kshirode Chandra Roy	Bangladesh	1982	1985
M. H. Abdel Aziz	Saudi Arabia	1982	1991
Krishna Prakash Srivastava	Ethiopia	1983	1989
Muhammad Siddique Chaudhry	U.S.A.	1983	1991
Wimala Tissa Weerakoon	Zambia	1983	1985
Harry D. Henderson	Lebanon	1984	1985
Mohammad Afzal	Pakistan	1984	1994
A. P. Kaloyanov	Bulgaria	1985	2013
Aalbert Anne Wanders	Netherlands	1988	2007
Ali Mahmoud El Hossary	Egypt	1988	2010
Chanchai Rojanasaroj	Thailand	1988	2011
Eltag S. Eldin Mahmoud	Sudan	1990	2011
Henrik Have	Denmark	1990	2009

Back Issues

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

(Vol.43, No.2, Spring, 2012-)

◇ ◇ ◇

Vol.44, No.3, Summer 2013

◇ ◇ ◇

Vol.44, No.4, Autumn 2013

SUPECIAL ISSUE: THE THEME:
What kind of cooperation do you want from the Japanese government, agricultural industry, agricultural engineering associations, engineers, developers and researchers to promote agricultural mechanization in the developing countries and homeland?

□ □ □

◇ ◇ ◇

Vol.45, No.1, Winter 2014

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INSTRUCTIONS TO AMA CONTRIBUTORS

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

Criteria for Article Selection

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

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

Rejected/Accepted Articles

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

Procedure

a. Articles for publication (original and one-copy) must be sent to AMA through the Co-operating Editor in the country where the article originates. (Please refer to the names and addresses of Co-operating Editors in any issue of the AMA). However, in the absence of any Co-operating Editor, the article needs to be sent to Co-operating Editor in the writer's neighboring country.
b. Contributors of articles for the AMA for the first time are required to attach a passport size ID photograph (black and white print preferred) to the article. The same applies to those who have contributed articles three years earlier. In either case, ID photographs taken within the last 6 months are preferred.
c. The article must bear the writer(s) name, title/designation, office/organization, nationality and complete mailing address.

Format/Style Guidance

a. Article must be sent on CD-R with MS DOS format (e.g. Word Perfect, Word for DOS, Word for Windows... **Absolutely necessary TEXT FORMAT**) along with two printed copy (A4).
b. The data for graphs and photographs must be saved into piecemeal dates and enclosed with the article.
c. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features:
   (i) brief and appropriate title;
   (ii) the writer(s) name, designation/title, office/organization; and mailing address;
   (iii) an abstract following ii) above;
   (iv) body proper (text/discussion);
   (v) conclusion/recommendation; and a
   (vi) bibliography
d. The printed copy must be numbered (Arabic numeral) successively at the top center whereas the disc copy pages should not be number. Tables, graphs and diagrams must likewise be numbered. Table numbers must precede table titles, e.g., "Table 1. Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Figure 1. View of the Farm Buildings".
e. **The data for the graph must also be included. (e.g. EXCEL for Windows)**
f. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
g. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
h. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
j. Convert national currencies in US dollars and use the later consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
l. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..."instead of 45 workers..., or, 5 tractors.

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Issued Quarterly

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