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AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.42, No.3, SUMMER 2011

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

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h. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
j. Convert national currencies in US dollars and use the later consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
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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AMA

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This is the 148th issue since its maiden isue in the Spring of 1971

EDITORIAL

By the end of last year, the price of the grain almost doubled compared to that of 2007. One of the reasons was the bursting population that is growing by more than 80 million each year. The world population had grown to 6.1 billion by 2000, and it is estimated to reach 7.3 billion by 2015, 8 billion by 2025, and 9.1 billion by 2050. In 2009, the number of undernourished people had marked one billion and more than 3 billion people today are in the poverty group.

Another reason for the rising food prices is because crops are turned into fuels. In the year 2000 for the U.S.A., the total amount of grain turned into ethanol fuel was only 16 million tons. However, in 2010, 126 million tons out of 400 million were turned into ethanol fuels. Of course, this is not only the problem of the U.S.A. Also, there is a large amount of sugar cane turned into ethanol in Brazil with production increasing year by year.

The usage of land is shifting from producing food into producing fuels. Under this situation, countries like China, economically growing rapidly and with plenty of capital, are starting to buy or borrow vast areas of agricultural lands from African countries to provide lands to produce food for their own country. About 140 million acres of land were traded in 2010, which is more than the whole agricultural land producing wheat and corn in U.S. It is estimated that these countries have paid more than 50 billion dollars to buy farmlands from developing countries. What is more, less than 40 % of the land bought by them was used to produce food. The rest of the lands are thought to be used for producing economic crops and bio fuels because they have more added value in the market.

Under such a situation, the rising price of food is a severe disadvantage to the poor in developing countries. In developed countries, people use only 10 % of their total income for food, but in developing countries, people use 70 to 80 % of their total income. This means that doubling food price is a critical situation for them. I think that one of the reasons so many riots are rising in many countries all over the world is the growing price of food.

Regarding these problems, we need to produce more food than now. However, the environmental problems around us, such as the desertification of farmlands and the depletion of groundwater in many countries, are serious matters. In China, more than 3,600 km^2 of land are turning into desert every year. In India, there are more than 20 million irrigation wells, but a big problem today is that the water level is lowering in all of them. To produce the maximum amount of food available from limited farmland, development of agricultural mechanization suitable for each region is very important. It is the task for the machinery today to work precisely in an appropriate time. To improve land productivity, promotion of global agricultural mechanization is needed.

It is thought that food will hover at a high price from now on. Including developing countries, it is an urgent task for all the countries to research and develop appropriate agricultural mechanization. AMA will continue to cooperate and give the best effort with people in the world who make their efforts for promoting agricultural mechanization.

Yoshisuke Kishida
Chief Editor

August, 2011

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Effect of Blade and Operational Parameters on Shredding Efficiency of an Experimental Cotton Stalk Shredder

by
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Abstract

The influence of the selected level of variables of three levels of blades (viz. 2, 3 and 4), four levels of peripheral velocity (viz. 21.52, 23.80, 26.58 and 28.60 ms^{-1}), three levels of blade thickness (viz. 2, 4 and 6 mm) and four levels of blade rake angle (viz. 0, 15, 30 and 45 deg) on shredding efficiency of an experimental cotton stalk shredder, in terms of length of cut of cotton stalk, was investigated. Increase in peripheral velocity from 21.52 to 28.60 ms^{-1} resulted in decreased length of cut. The lowest value of length of cut was 113.83 mm with 2 blades, 0 deg blade rake angle and 28.60 ms^{-1} peripheral velocity. At 0 deg blade rake angle, the length of cut of shredded cotton stalk was much lower than other blade rake angles at 6 mm blade thickness. Increase in number of blades from 2 to 4 resulted in increased length of cut for all the levels of blade rake angle. Increase in blade rake angle from 0 to 45 deg resulted in increased length of cut for all levels of peripheral velocity and number of blades. Two blades with 0º blade rake angle, 6 mm blade thickness and 28.60 ms^{-1} peripheral velocity recorded the lowest value of length of cut.

Introduction

One of the difficulties in cotton production is the need to clear the ground from old cotton plants after harvesting. Only manual uprooting or cutting the stalks are followed, which is highly labour intensive. Some farmers used repeated heavy disking to cut the cotton stalk and cover it with soil. Incorporation of cotton stalks into the soil ensures rapid decomposition. The most rapid decomposition occurs when residue is placed 10 cm deep. Shredding stalks as finely as possible also allows for rapid decomposition. Hence, the type of shredding mechanism should be selected based on the efficiency in terms of finished dimensions of the stalk required for incorporation in the soil to facilitate quick decomposition. A rotary cutter is an implement in the mechanization chain of crop production. After harvesting the crop, these machines cut the stalk and distribute them on the field surface. The rotary cutter consists of blades pivoted horizontally on a vertical shaft and moves forward on the field. Rotary

Acknowledgement

The author expresses deep gratitude to Council of Scientific and Industrial Research for providing financial assistance for conducting this study.

cutters are generally used in shredding crop stalks. They are simple and sturdy in construction, with less wearing parts and, therefore, the frictional power loss is minimum (Guzel and Zeren, 1990). Hence, an impact type rotary blade shredder was selected for investigation.

Review of Literature

Guzel and Zeren (1990) suggested that a rotary cutter is an implement in the mechanization chain of cotton production. After harvesting the cotton, these machines cut the cotton stalk and distribute them on the field surface. Rider and Barr (1976) reported that the uniformity of cut and cutting efficiency depended upon the shape of the rotating knives. Specially shaped knives were used in forage harvesters. The number of knives, for a given cutter head diameter, determined the amount of space between knives for material to flow in and out during the operation. The cutting angle was an important design factor in the knife shape. The cutting angle was defined as the angle between the beveled edge of the knife, which needed the crop entering the cutter head, and inside the surface of the knife. A smaller cutting angle provided a more uniform cut, but a larger angle increased knife strength. A compromise angle of 30 to 45 deg is commonly used.

Chattopadhyay and Pandey (1999) suggested that the minimum cutting speed increased from 12.9 to 18.0 ms^{-1} for a knife rake angle of 20 to 60 deg. O'Dogherty (1982) stated that the specific energy was inversely proportional to the mean chop length; or the power required to cut forage material was inversely proportional to chop length for a given machine throughput. High energy consumption will result in short crop lengths.

Materials and Methods

The efficiency of a shredder is the ability to cut the crops/straw/stalk into very small pieces. The impact type rotary cutter performance depends mainly on the design of rotating blades. Many factors are involved in rotary cutter design. The most significant features of the rotating blades are number of blades, peripheral velocity, thickness and rake angle. It is evident that the variables (viz. number of blades, velocity of blade, blade thickness and rake angle) have a profound effect on the shredding efficiency in terms of finished dimensions of shredded pieces. For achieving maximum shredding efficiency of cotton stalks the following variables were selected for the investigation.

1. Number of blades
2. Peripheral velocity
3. Blade thickness
4. Rake angle

The performance of the shredder is assumed to be optimum when the cutting and shredding of the stalks results in small pieces.

Effect of Selected Levels of Variables on Length of Cut

A total number of 432 experiments were conducted using the experimental set up. The investigation was carried out with three levels of number of blades (viz. 2, 3 and 4), four levels of peripheral velocity (viz. 21.52, 23.80, 26.58 and 28.60 ms^{-1}), three levels of blade thickness (viz. 2, 4 and 6 mm) and four levels of blade rake angle (viz. 0, 15, 30 and 45 deg). The moisture content of the cotton stalks was maintained constant (95.30 percent dry basis) throughout all experiments. The values of finished dimensions of cotton stalks in terms of length of cut were recorded for all treatments. The effect of selected levels of variables on finished dimensions of the cotton stalk in terms of length of cut was analyzed.

Results and Discussion

Effect of Selected Variables on Length of Cut

Effect of Peripheral Velocity on Length of Cut for 2 Mm Thickness (T_1)

The relationship between the length of cut and the peripheral velocity for the 2 mm blade thickness for different levels of blade rake angle and number of blades is depicted in **Fig. 1**.

An increase in peripheral velocity from 21.52 to 28.60 ms^{-1} resulted in decreased length of cut. The above result was in conformity with the findings of Manjeet Singh *et al.* (1998). The lowest value of length of cut was observed at the shredder with 2 (N_1) blades and 28.60 ms^{-1} (S_4) peripheral velocity.

Effect of Peripheral Velocity on Length of Cut at 4 Mm Thickness (T_2)

An increase in peripheral velocity from S_1 to S_4 resulted in decreased length of cut for 2, 3 and 4 blades (**Fig. 2**).

Effect of Peripheral Velocity on Length of Cut at 6 Mm Blade Thickness (T_3)

An increase in peripheral velocity from 21.52 to 28.60 ms^{-1} resulted in decreased length of cut. The above result was in conformity with the findings of Manjeet Singh *et al.* (1998). The lowest value of length of cut of 113.83 mm was at the shredder with 2 blades, 0 deg blade rake angle and 28.60 ms^{-1} peripheral velocity (**Fig. 3**).

A 0 deg blade rake angle and S4 level of peripheral velocity combination recorded lowest value of length of cut when compared with other combinations. In the case of number of blades, 2 blades with 0 deg blade rake angle and 28.60 ms^{-1} peripheral velocity recorded lowest value of length of cut. Increase in blade rake angle from 0 to 45 deg resulted in increased length of cut for all the levels of peripheral velocity and number of blades.

Statistical Analysis and Mathematical Modeling

The analysis of variance for the torque requirement to shred the cotton stalk is furnished in **Table 1**. All the interaction effects were significant at the one percent level.

Regression Equation for Length of Cut

The multiple linear regression equation fitted for the length of cut in shredding cotton stalk is given below.

$Y = 252.070 + 8.341^{**} X_1 - 0.1^{**} X_2 - 3.6^{**} X_3 + 1.507^{**} X_4$

$R^2 = 0.71^{**}$

R^2 *(adjusted for DF)* $= 0.70^{**}$

** Significant at 1 percent level

The R-square value of 0.71 was significant at the one percent level of probability, which showed that a unit increase in X_1 (number of blades) ceteris paribus would result in an increase of 8.341 units of Y, a unit increase in X_2 (peripheral velocity) ceteris paribus would result in decrease of 0.1 units of Y, a unit increase in X_3 (blade thickness) ceteris paribus would result in decrease of 3.6 units of Y, where as a unit

Fig. 1 Effect of peripheral velocity on Length of cut at 2 mm blade thickness (T_1)

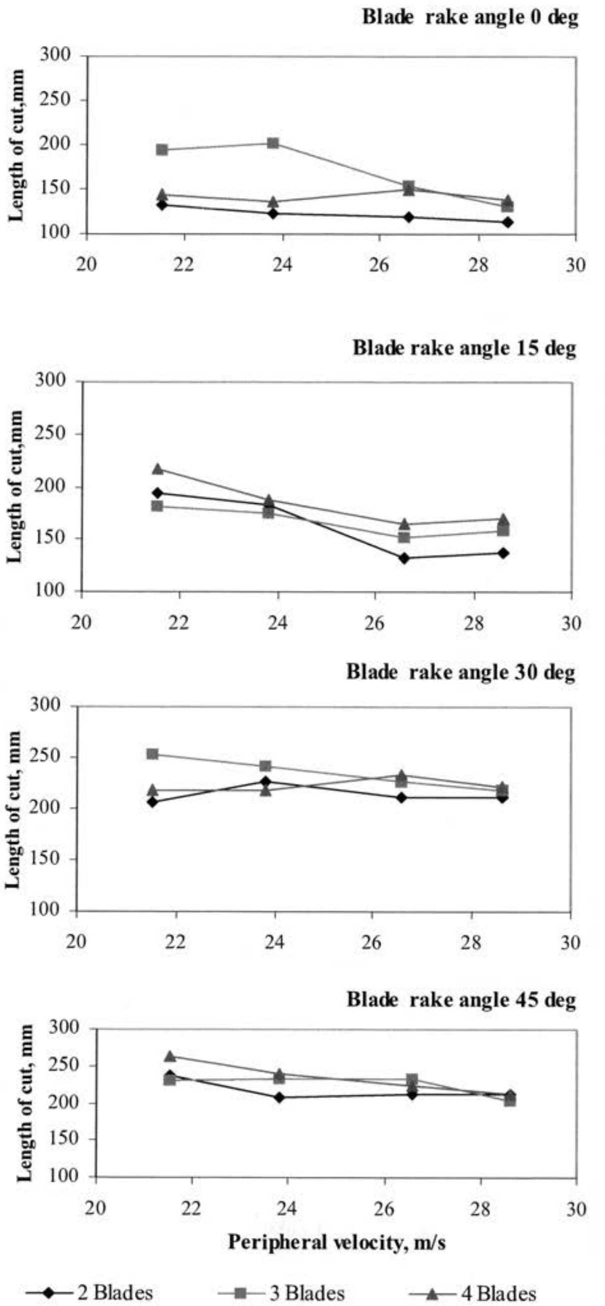
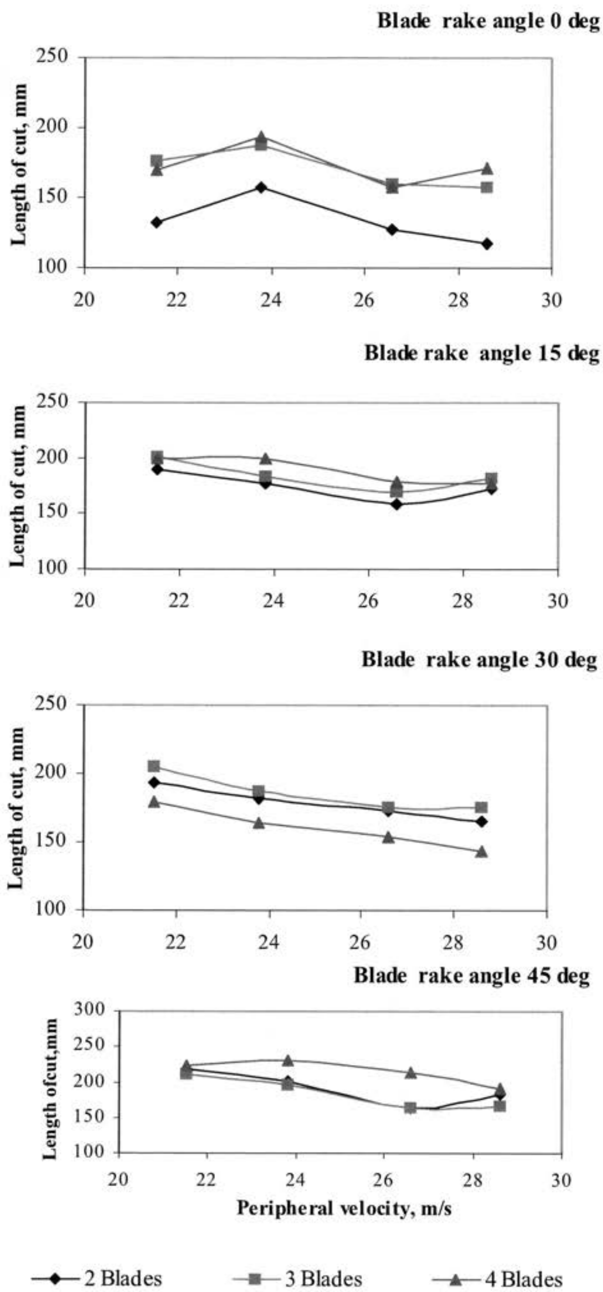


Fig. 2 Effect of peripheral velocity on length of cut at 4 mm blade thickness (T_2)



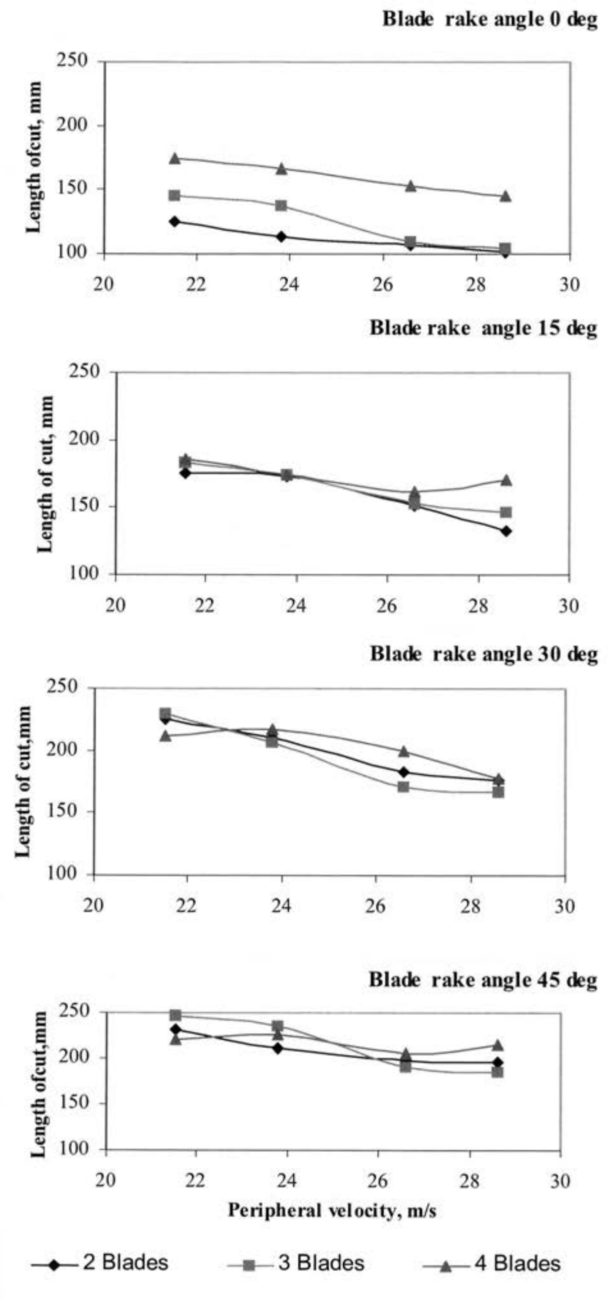
increase in X_4 (blade rake angle) ceteris paribus would result in an increase of 1.507 units of Y.

Optimization of Variables for Cotton Stalk Shredder

The selected level of variables have to be optimized for achieving the maximum shredding efficiency reflected in terms of minimum length of cut of shredded cotton stalk. The lowest mean values of torque, energy required to shred cotton stalk and length of cut for different interaction of the selected level of variables are analyzed.

It was observed that the combination of $N_1S_4T_3\theta_1$ resulted in the lowest length of cut of shredded cotton stalk of 101.00 mm.

Fig. 3 Effect of peripheral velocity on Length of cut at 6 mm blade thickness (T_3)



Conclusions

Influence of the selected level of variables on shredding efficiency in terms of length of cut of shredded cotton stalk was investigated. Increase in peripheral velocity from 21.52 to 28.60 ms^{-1} resulted in decreased length of cut. The lowest value of length of cut of 113.83 mm was observed at the shredder with 2 blades, 0 deg blade rake angle and 28.60 ms^{-1} peripheral velocity. At 0 deg blade rake angle, the length of cut of shredded cotton stalk was much lower than other blade rake angles at 6 mm blade thickness. Increase in number of blades from 2 to 4 resulted in increased length of cut for all the levels of blade rake angle. Increase in blade rake angle from 0 to 45 deg resulted in increased length of cut for all the levels of peripheral velocity and number of blades. For achieving maximum shredding efficiency, the combination of 2 blades, 28.60 ms^{-1} peripheral velocity, 6 mm blade thickness and 0 deg blade rake angle was selected.

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O'Dogherty, M. J. 1982. A review of research on forage chopping. J. of Agric. Engg. Res., 27: 267-289.

Rider and Barr. 1976. Crop production equipment, Forage harvesters and blowers.

■■

Table 1 ANOVA for Length of cut

SV	DF	SS	MS	F
Treatments	143	529,454.0658	3,702.4760	59.02**
Peripheral velocity (S)	3	68,373.9834	22791.3278	363.33**
Blades (N)	2	21,388.7679	10,694.3840	170.48**
Rake angle (θ)	3	282,620.0294	94,206.6765	1501.79**
Thickness (T)	2	17,983.6976	8,991.8488	143.34**
S × N	6	3,787.3800	631.2300	10.06**
S × θ	9	3,455.7368	383.9708	6.12**
S × T	6	2,309.8409	384.9735	6.14**
N × θ	6	19,459.5069	3,243.2511	51.70**
N × T	4	4,442.6428	1,110.6607	17.71**
θ × T	6	59,291.1677	9,881.8613	157.53**
S × N × θ	18	5,889.1903	327.1772	5.22**
S × N × T	12	3,563.1565	296.9297	4.73**
S × θ × T	18	9,306.1256	517.0070	8.24**
N × θ × T	12	16,973.8435	1,414.4870	22.55**
S × N × θ × T	36	10,608.9965	294.6943	4.70**
Error	288	18,066.1267	62.7296	
Total	431	547,520.1925		

cv = 13.6% ** = significant at 1% level; * = significant at 5% level ns = not significant

NEWS

IWABE

International Workshop on Agricultural and Bio-systems Engineering (IWABE)─2011

December 2nd- 3rd, 2011

Nong Lam University, Hochiminh City, Vietnam

INTERNATIONAL WATER EXHIBITION: The Organizing Committee is pleased to inform you that the International Workshop on Agricultural and Bio-systems Engineering will be held at Nong Lam University, Hochiminh city, Vietnam on December 2nd- 3rd, 2011. This workshop is co-organized by Nong Lam University, the Kyushu Branch of JSAM (Japanese Society of Agricultural Machinery), Mie University (Japan) and Sung Kyung Kwan University (Korea) andmainly sponsored by The Viet Nam Ministry of Education and Training.

It is our great pleasure to invite you to attend the IWABE and present papers of your most recent works. The IWABE will provide a venue for ideas exchanges and information on the current research and technology developments in the field of Agricultural and Bio-systems Engineering. Our hope is to bring fruitful meeting for all participants and also to facilitate an enjoyable visit in Hochiminh City.

http://fme.hcmuaf.edu.vn/contents

Field Evaluation of the Developed Experimental Cotton Picking Aid: Part II

by

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Abstract

Preliminary testing of the developed picking aid was done in the field using various combinations of the picker end diameters (20, 25, 32 and 40 mm) and suction pressures (25, 30, 35, 40, 45 and 50 mm of Hg) to study their effect on picking efficiency, trash content and output capacity. For assessing the parameters at a uniform level of suction pressures, extrapolation of the trend line had to be used to estimate picking efficiency, trash content and output capacity. Maximum picking efficiency of 96.3 % was achieved at a picker end diameter of 25 mm with a suction pressure of 45 mm of Hg. Minimum trash content of 0.65 % was observed at a picker end diameter of 20 mm with suction pressure of 30 mm of Hg. Maximum output capacity of 6.25 kg/h was achieved at a picker end diameter of 25 mm with suction pressure of 45 mm of Hg. The picking aid was then evaluated for long term field trials with the optimized picker end diameter (25 mm) at varying suction pressures (35, 40, 45 and 50 mm of Hg) for two stages of picking. Though the picking efficiency and output capacity was maximum at 50 mm suction pressure for the first picking, trash content increased at this suction pressure. However, minimum trash content of 5.7 % was obtained at 35 mm of Hg with a picking efficiency of 93.9 % and output capacity of 4.2 kg/h. Similarly, for the second stage of picking, minimum trash content of 4.39 % was at 35 mm suction pressure with picking efficiency of 92.8 % and output capacity of 4.01 kg/h.

Introduction

Cotton, the king of fibres, is an industrial commodity of global importance. Besides being a monetary spinner, it is an employment generator as its cultivation provides employment of 200 man-days/ha. About 60 million people earn their livelihood through its cultivation, trade and processing (Reddy, 2004). Production of cotton in India has gone up from 3.04 million bales (of 170 kg each) in 1950-51 to 18.49 million bales in 2005-06. The area under cotton was 5.88 million hectares in 1950-51 and rose to 8.67 million hectares in 2005-06. The average yield of cotton jumped to from 88 kg per hectare in 1950-51 to 362 kg per hectare in 2005-06 (Anon., 2007a). In Punjab, the area under cotton and production from cotton was 557 thousand hectares and 2395 thousand bales in 2005-2006. The average lint yield for the state was 731 kg per hectare (Anon., 2007b), much above the national average, and highest in the country. Sharma and Goyal (1999) used a commercially available vacuum cleaner (electrically operated) for picking cotton but the equipment needed modification due to low suction pressure and clogging. It was also suggested that a vacuum device should be operated with a light weight petrol engine. They also reported that there were three manual pickings in a crop season at an approximate interval of 15 days. The first, second and the third picking constituted 35, 50 and 15 % of the cotton yield, respectively.

Sandhar and Goyal (2003) developed a vacuum based cotton picker consisting of a suction blower, tank and a suction hose. The drive to the blower was provided from the tractor PTO through a gear box. The picking efficiency was in the range of 63.4 to 77.5 % at a suction pressure of 240 mm of water head at a blower speed of 2,875 rpm. The machine picked the fully open bolls only and left the immature, infected and those bolls rigidly adhered to the carpel. The left-over manually picked cotton after machine operation ranged between 22.5 to 36.6 %. Rangasamy *et al.* (2006) optimized the machine parameters of a pneumatic knapsack cotton picker such as pickup diameter, filter type, filter height, capacity of collection drum and speed of aspirator through statistical analysis. The field capacity for the first picking (4.93 kg/h) was less than that for the third picking (5.07 kg/h). The picking efficiency was lower (96.35 %) in the first picking and higher (97.48 %) in third picking. The trash content in the machine picked cotton was a maximum of 13.97 % in the third picking. The saving in cost, time, and energy in machine picking compared to conventional picking was 9.00, 75.00 and 68.23 %, respectively.

Cotton picking is mostly done manually in India. It is not only tedious work but also ten times costlier than the cost of irrigation and about twice the cost of weeding operation (Prasad and Majumdar, 1999). Cotton picking season coincides with harvesting of rice and field preparation for wheat, thus, the farmer experiences a shortage of labour during the picking season. Due to impending scarcity of labour, mechanization of cotton harvesting is of paramount importance. In view of the above, a mechanical picking aid was developed and its field performance evaluated.

Table 1 Picker end diameter and suction pressures of picking aid

Picker end	Diameter size (mm)	Suction pressure (mm of Hg)			
D_1	20	30	35	40	50
D_2	25	25	30	35	45
D_3	32	20	25	30	35
D_4	40	15	20	25	30

Materials and Methods

A mechanical cotton picking aid already designed and developed in the Department of Farm Power and Machinery, PAU during the year 2007-08 as per the details given in **Figs. 1** and **2** was experimentally evaluated under field conditions in the research farm of the Department of Farm Power and Machinery, PAU Ludhiana. The complete details about the design and development of the experimental picking aid are given in a separate paper entitled "Design and Development of Experimental Cotton Picking Aid: Part I" (Sharma *et al.,* 2011). Independent and dependent variables selected for this study are given below.

Independent Parameters

Independent parameters used for the study were picker end diameter and suction pressure. During preliminary field trials, four picker end diameters were tested: D_1 (20 mm), D_2 (25 mm), D_3 (32 mm) and D_4 (40 mm). Each picker end diameter was tested at four suction pressures (**Table 1**) with the four suction pressures being different for each picker end diameter. Variation in suction was due to the different sizes of the picker end diameters.

Dependent Parameters

The dependent parameters measured were picking efficiency, trash

Fig. 1 Side elevation of experimental picking aid (all dimensions are in mm)

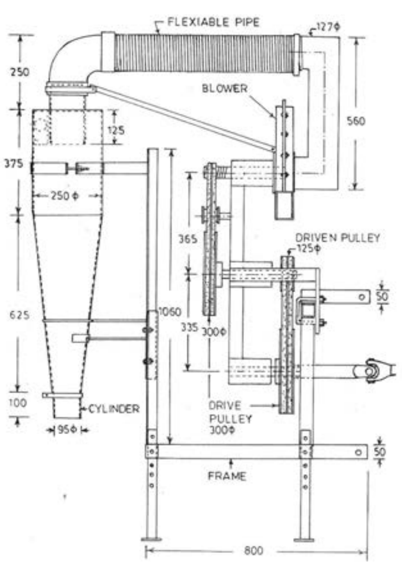
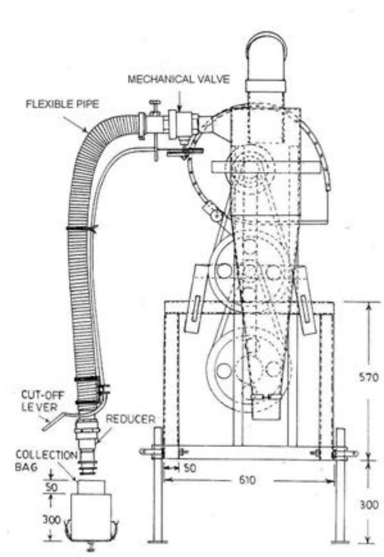


Fig. 2 Front elevation of experimental picking aid (all dimensions are in mm)



content and output capacity.

Picking Efficiency

The picking efficiency (η_p) was determined by dividing the weight of seed cotton picked by the machine (W_{mc}) by the weight of total seed cotton (W_t) (weight of seed cotton picked by the machine plus the weight of the left over seed cotton picked manually (W_m) after machine operation) as shown by the following formula:

$$\eta_p(\%) = W_{mc} / W_t \times 100$$

$$W_t = W_{mc} + W_m$$

Trash Content

The weight of trash content (W_{tc}) was determined by manually separating the trash from the sample (W_s) of machine picked cotton. The trash content percentage (T_c) was determined by the following formula:

$$T_c = (W_{tc} / W_s) \times 100$$

Output Capacity

The output capacity (OC) was obtained by the ratio of the weight of seed cotton picked by the machine (W_{mc}) to the time taken to pick the cotton (t_{mc}) as shown by the following formula:

$$OC = W_{mc} / t_{mc}$$

Preliminary Testing

The machine was tested at the research farm of the Department of Farm Power and Machinery, Punjab Agricultural University, Ludhiana for Ankur 651 cotton variety with an average boll size of 55 mm. A 35 hp tractor (TAFE 1035) was used as a source of power to operate the machine in the field. There were 16 plots, each 4 m × 2 m, with one row 4 m long. These plots were divided into a set of four plots each. D_1 = 20 mm picker end diameter was used in the first plot. D_2 = 25 mm picker end diameter was used in the second plot. Similarly, D_3 = 32 mm and D_4 = 40 mm picker end diameter was used for picking in the third and fourth plot. During the picking of first four plots, the speed of the blower was kept fixed at 4,000 rpm. The procedure was again repeated for the second, third and fourth set of plots and keeping the blower speed fixed at 4,400 rpm (for second set of four plots and by using D_1, D_2, D_3 and D_4 picker end diameters), 4,800 rpm (for third set of four plots and by using D_1, D_2, D_3 and D_4 picker end diameters) and 5,200 rpm (for fourth set of plots and using D_1, D_2, D_3 and D_4 picker end diameters). The use of different picker end diameters led to the creation of different suction pressures which were recorded separately during the experimentation. Corresponding to each picker end diameter, four different suction pressures were obtained such as 30, 35, 40 and 50 mm of Hg for D_1 (20 mm), 25, 30, 35 and 45 mm of Hg for (25 mm), 20, 25, 30 and 35 mm of Hg for D_3 (32 mm) and 15, 20, 25 and 30 mm of Hg for D_4 (40 mm). The same procedure was followed for the replications. After field testing, the results have been discussed for picking efficiency, trash content and output capacity by taking the effect of suction pressure and picker end diameter for a fixed blower speed. Trend line equations were also developed for picking efficiency, trash content and output capacity for different suction pressures. Statistical analysis was also performed for the selected levels of suction pressures at each picking end diameter.

Long Duration Testing

After the preliminary testing, long duration testing of the machine was performed at optimal picker end diameter by varying suction pressures (35, 40, 45 and 50 mm of Hg) selected on the basis of preliminary testing. Combination of optimum picker end diameter (25 mm) and each suction pressure was tested on four plots each of size 23 m × 8 m for available crop variety for two stages of picking: i.e. first and second picking stage. The picker end diameter was kept the same for all the plots but suction pressure was varied by changing blower speed.

Fig. 3 Effect of operational parameters on picking efficiency

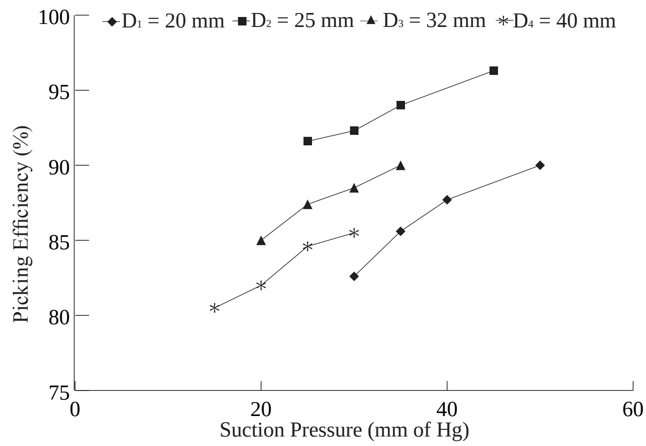
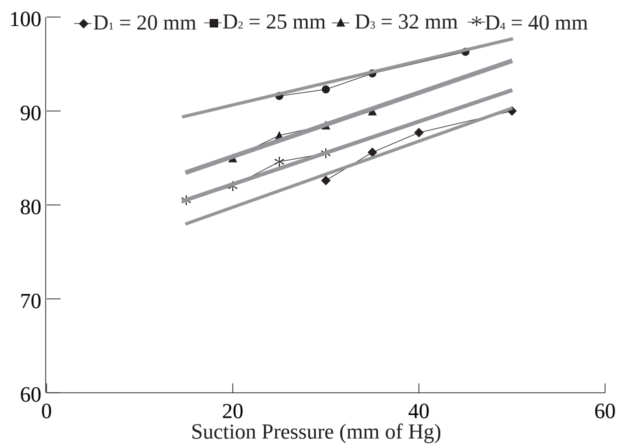


Fig. 4 Extrapolation of trends of picking efficiency



Results and Discussion

Results obtained were analyzed in two sections: i.e. preliminary testing and long duration testing.

Preliminary Testing

Effect of Suction Pressure and Picker end Diameter on Picking Efficiency

For 20 mm picker end diameter, the suction pressures were 30, 35, 40 and 50 mm of Hg and the corresponding picking efficiencies were 82.60, 85.60, 87.70 and 90.0 %, respectively. Similarly, at 25 mm picker end diameter, for the available suction pressures of 25, 30, 35 and 45 mm of Hg, the corresponding picking efficiencies were 91.60, 92.30, 94.0 and 96.30 %, respectively. Further, at 32 mm picker end diameter, the suction pressures were 20, 25, 30 and 35 mm of Hg and the corresponding picking efficiencies were 85.0, 87.40, 88.50 and 90.0 %, respectively. Again, at 40 mm picker end diameter, the suction pressures were 15, 20, 25 and 30 mm of Hg and the corresponding picking efficiencies were 80.50, 82.0, 84.60 and 85.50 %, respectively. Maximum picking efficiency of 96.30 % was achieved at 25 mm picker end diameter at a suction pressure of 45 mm of Hg. Minimum picking efficiency of 80.5 % was achieved at 40 mm picker end diameter at a suction pressure of 15 mm of Hg. The reason for the highest picking efficiency at 25 mm picker end diameter was that higher suction pressure developed and there was sufficient size of picker end diameter for the cotton bolls to be picked easily. With the selected suction pressures corresponding to each picker end diameter a graphical representation was plotted and the trend of picking efficiency corresponding to developed suction pressure was obtained as shown in **Fig. 3**. Extrapolation of these trend lines are shown in **Fig. 4**. Empirical relationships were developed for each picker end diameter.

At D_1 (20 mm) the relationship between suction pressure (x) and picking efficiency (y_{20}) was

$$y_{20} = 0.3583x + 72.591, \quad (R^2 = 0.95) \qquad (1)$$

At D_2 (25 mm): the relationship between suction pressure (x) and picking efficiency (y_{25}) was

$$y_{25} = 0.2434x + 85.334, \quad (R^2 = 0.98) \qquad (2)$$

At D_3 (32 mm): the relationship between suction pressure (x) and picking efficiency (y_{32}) was

$$y_{32} = 0.328x + 78.87, \quad (R^2 = 0.95) \qquad (3)$$

At D_4 (40 mm): the relationship between suction pressure (x) and picking efficiency (y_{40}) was

$$y_{40} = 0.352x + 75.23, \quad (R^2 = 0.96) \qquad (4)$$

Picking efficiency corresponding to 20 mm picker end diameter at suction pressures of 25 and 45 mm of Hg had to be extrapolated from **Eqn. 1** and these values were 81.50 and 90 %. Similarly, picking efficiencies corresponding to picker end diameter 25 mm at suction pressure of 40 and 50 mm of Hg, after extrapolating **Eqn. 2**, were 95.07 and 97.5 %. Again, at picker end diameter of 32 mm, corresponding to suction pressures of 40, 45 and 50 mm of Hg, picking efficiencies obtained from **Eqn. 3** were 91.90, 93.63 and 95.27 %, respectively. At picker end diameter of 40 mm, corresponding to suction pressures of 35, 40, 45 and 50 mm of Hg, picking efficiencies obtained from **Eqn. 4** were 87.55, 89.31, 91.07 and 92.83 %, respectively. Average of picking efficiencies obtained from field as well as theoretically computed efficiencies are shown in **Table 2**. The analysis showed that the picker end diameter and suction pressure affected the picking efficiency significantly at the 5 % level. Results also indicated that effect of interaction of both the factors were non significant at the 5 % level.

Table 2 Effect of different suction pressure and picker end diameter on picking efficiency

Picker end diameter (mm)	Picking efficiency (%)					
	Suction pressure (mm of Hg)					
	25	30	35	40	45	50
20	81.50	82.60	85.60	87.70	88.70	90.00
25	91.60	92.30	94.00	95.07	96.30	97.50
32	87.40	88.50	90.00	91.90	93.63	95.27
40	84.60	85.50	87.55	89.31	91.07	92.83

Effect of Suction Pressure and Picker end Diameter on Trash Content

At 20 mm picker end diameter, the suction pressures were 30, 35, 40 and 50 mm of Hg and the corresponding trash contents were 0.65, 1.01, 1.24 and 1.54 %, respectively. At 25 mm picker end diameter, the suction pressures were 25, 30, 35 and 45 mm of Hg and the corresponding trash contents were 1.26, 1.76, 1.88 and 2.30 %, respectively. Again, at 32 mm picker end diameter, the suction pressures were 20, 25, 28 and 35 mm of Hg and the corresponding trash contents were 1.61, 1.94, 2.16 and 2.57 %, respectively. At 40 mm picker end diameter, the suction pressures were 15, 20, 25 and 30 mm of Hg and the corresponding trash contents were 3.03, 3.53, 4.30 and 5.64 %, respectively. Maximum trash content of 5.64 % was at 40 mm picker end diameter at 30 mm suction pressure and the minimum trash content of 0.65 % was at 20 mm of picker end diameter at 30 mm suction pressure. The reason for the lowest trash content at 20 mm of picker end diameter was that a smaller size of opening (diameter) resulted in less trash. Although, at 20 mm picker end diameter, the trash content was lowest, but picking efficiency was also lower. On the other hand, trash content at 25 mm picker end diameter was slightly higher as compared to trash content at 20 mm picker end diameter. With the available suction pressures corresponding to each picker end diameter, a graph was plotted and trend of trash content for each picker end diameter corresponding to available suction pressure was obtained (**Fig. 5**). Extrapolation of these trend lines were also made (**Fig. 6**) and different equations were developed for each picker end diameter.

The equation developed for assessing trash content corresponding to D_1 (20 mm) was

$$y_{20} = 0.043x - 0.5551, \quad (R^2 = 0.95) \quad (5)$$

The equation developed for assessing trash content corresponding to D_2 (25 mm) was

$$y_{25} = 0.0485x + 0.1646, \quad (R^2 = 0.94) \quad (6)$$

The equation developed for assessing trash content corresponding to D_3 (32 mm) was

$$y_{32} = 0.0642x + 0.3379, \quad (R^2 = 0.99) \quad (7)$$

The equation developed for assessing trash content corresponding to D_4 (40 mm) was

$$y_{40} = 0.172x + 0.225, \quad (R^2 = 0.95) \quad (8)$$

Trash contents corresponding to suction pressures of 25 and 45 mm for picker end diameter D_1 (20 mm), as obtained from **Eqn. 5**, were 0.51 and 1.37 %, respectively. At picker end diameter D_2 (25 mm) and suction pressures of 40 and 50 mm, corresponding trash contents, obtained from **Eqn. 6**, were 2.1 and 2.58 %, respectively. Similarly, trash contents corresponding to picker end diameter D_2 (25 mm) at suction pressure of 40, 45 and 50 mm, obtained from **Eqn. 7**, were 2.90, 3.22 and 3.54 %, respectively. At picker end diameter D_4 (40 mm), trash contents at suction pressures of 35, 40, 45 and 50 mm, obtained from **Eqn. 8**, were 6.27, 7.13, 7.99 and 8.85 %, respectively. Average trash contents obtained from field and that generated from the equations are shown in **Table 3**. The analysis showed that the picker end diameter and suction pressure affected the trash content significantly at the 5 % level. Results also indicated that effect of interaction of both the factors was significant at the 5 % level.

Table 3 Effect of different suction pressures and picker end diameters on trash content

Picker end diameter (mm)	Trash content (%)					
	Suction pressure (mm of Hg)					
	25	30	35	40	45	50
20	0.51	0.65	1.01	1.24	1.37	1.54
25	1.26	1.76	1.88	2.10	2.30	2.58
32	1.94	2.16	2.57	2.90	3.22	3.54
40	4.30	5.64	6.27	7.13	7.99	8.85

Effect of Suction Pressure and Picker end Diameter on Output Capacity

At 20 mm picker end diameter and suction pressures of 30, 35, 40 and 50 mm the corresponding output capacities were 3.00, 3.15, 3.50 and 4.55 kg/h, respectively. At 25 mm picker end diameter and suction pressures of 25, 30, 35 and 45 mm, the corresponding output capacities were 4.50, 4.89, 5.15 and 6.25 kg/h, respectively. At 32 mm picker end diameter and suction pressures of 20, 25, 30 and 35 mm the corresponding output capacities were 3.76, 4.20, 4.60 and 5.10 kg/h, respectively. Finally, at 40 mm picker end diameter and suction pressures of 15, 20, 25 and 30 mm of Hg and the corresponding output capacities were 2.51, 2.70, 3.10 and 3.65 kg/h, respectively. Maximum output capacity of 6.25 kg/h was achieved at 25 mm picker end diameter with suction pressure of 45 mm of Hg. Minimum output capacity of 2.51 kg/h was observed at 40 mm picker end diameter at a suction pressure of 15 mm of Hg. Highest output capacity was achieved at 25 mm of picker end diameter due to high suction pressure developed and optimal

Fig. 5 Effect of operational parameters on trash content

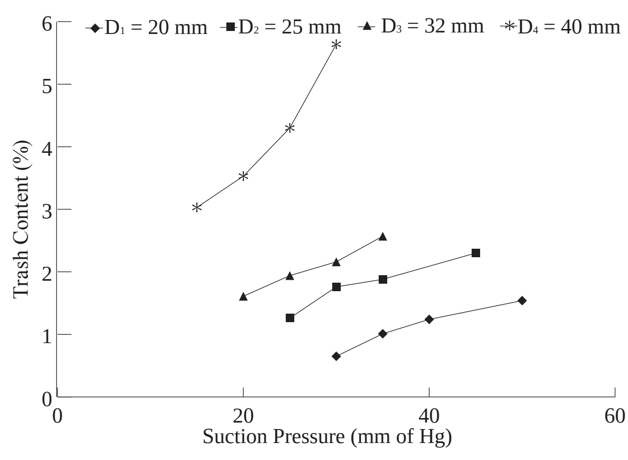


Fig. 6 Extrapolation of trends of trash content

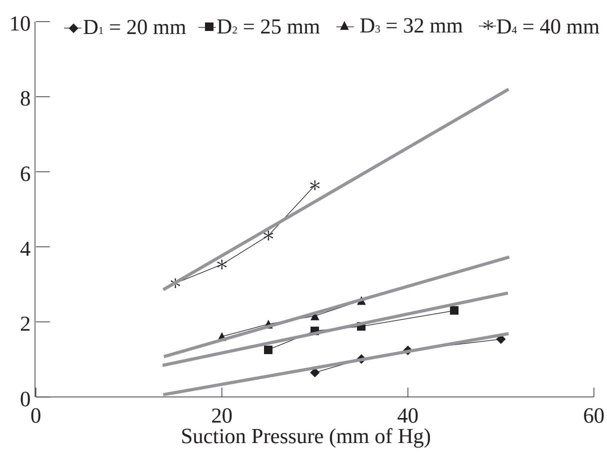


Table 4 Effect of different suction pressures and picker end diameters on output capacityt

Picker end diameter (mm)	Output capacity (kg/h) Suction pressure (mm of Hg)					
	25	30	35	40	45	50
20	2.45	3.00	3.15	3.50	4.05	4.55
25	4.50	4.89	5.15	5.74	6.25	6.60
32	4.20	4.60	5.10	5.59	6.04	6.49
40	3.10	3.65	3.94	4.30	4.70	5.09

size of picker end diameter allowing easy picking of cotton bolls. Therefore, for optimal performance: i.e. maximizing cotton output and picker efficiency with minimum trash content, picker end diameter should be set at 25 mm. A graph was plotted for assessment of the trend of output capacity for each picker end diameter corresponding to the developed suction pressure (**Fig. 7**). Extrapolation of these trend lines was done as shown in **Fig. 8** and different equations were also developed for each picker end diameter.

The equation for assessing output capacity corresponding to D_1 (20 mm) was

$y_{20} = 0.08x + 0.45$,

$(R^2 = 0.95)$ ....(9)

The equation for assessing output capacity corresponding to D_2 (25 mm) was

$y_{25} = 0.087x + 2.2603$,

$(R^2 = 0.97)$ ....(10)

The equation for assessing output capacity corresponding to D_3 (32 mm) was

$y_{32} = 0.0905x + 1.9713$,

$(R^2 = 0.98)$ ....(11)

The equation for assessing output capacity corresponding to D_4 (40 mm) was

$y_{40} = 0.0764x + 1.271$,

$(R^2 = 0.95)$ ....(12)

The values of output capacity corresponding to picker end diameter of D_1 (20 mm) at suction pressures of 25 and 45 mm obtained from equation (9) were 2.45 and 4.05 kg/h, respectively. The values of output capacity corresponding to picker end diameter D_2 (25 mm) at suction pressures of 40 and 50 mm calculated from **Eqn. 10** were 5.74 and 6.6 kg/h, respectively. Similarly, at picker end diameter D_3 (32 mm), values of output capacity at suction pressures of 40, 45 and 50 mm obtained from **Eqn. 11** were 5.59, 6.04 and 6.49 kg/h, respectively. At picker end diameter D_4 (40 mm), values of output capacity at suction pressures of 35, 40, 45 and 50 mm obtained from **Eqn. 12** were 3.94, 4.30, 4.70 and 5.09 kg/h, respectively. Average output capacity obtained from the field and those generated from the equations are shown in **Table 4**. The results of analysis showed that the picker end diameter and suction pressure affected the output capacity significantly at the 5 % level. Results also indicated that effect of interaction of both the factors was significant at 5 % level.

Performance Evaluation at Optimized Picker end Diameter

Based on the data collected and analyzed from preliminary testing, the optimum independent parameters were selected for long run testing.

First and Second Stage of Picking

The effect of suction pressures and picker end diameter of 25 mm on picking efficiency, trash content and output capacity for first and second stage of picking is shown in **Table 5**. It can be seen that for first and second stage of picking, at 25 mm picker end diameter, all the three dependent parameters: i.e. picking efficiency, output capacity and trash content increased with increase in the suction pressure. The picking efficiency and output capacity were maximum at 50 mm suction pressure and, also, trash content increased at 50 mm suction pressure. Thus, optimization of the picking efficiency and output capacity can be resolved by arbitrarily choosing the picking efficiency of 95 % with

Fig. 7 Effect of operational parameters on output capacity

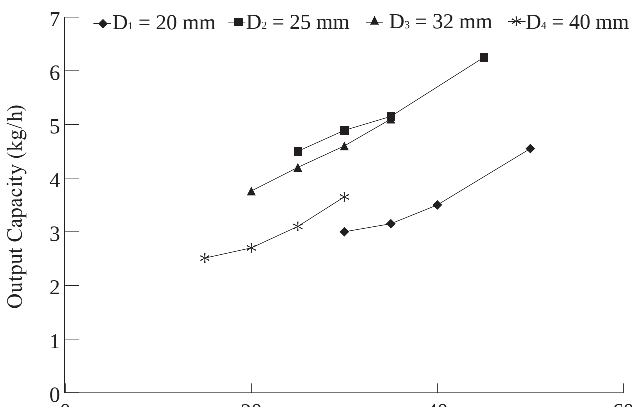
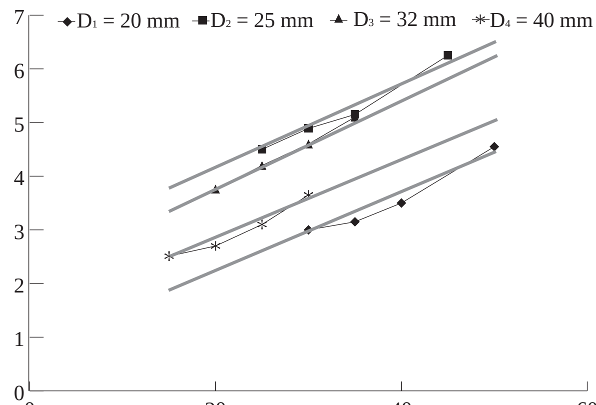


Fig. 8 Extrapolation of trend of output capacity



5 % trash content that provides an output of 4.50 and 4.30 kg/h. However, if the trash content at higher levels is also admissible: i.e. up to 7.23 or 8.30 %, then an output capacity and picking efficiency of 5.31 or 5.12 and 97.20 or 96.60 for first or second picking, respectively, can also be obtained.

Conclusions

1. The picking efficiency increased with the increase of suction pressure and with a decrease of picker end diameter. Maximum picking efficiency of 96.30 % was achieved at 25 mm picker end diameter with a suction pressure of 45 mm of Hg. Minimum picking efficiency of 80.50 % was achieved at 40 mm picker end diameter with a suction pressure of 15 mm of Hg.
2. The trash content increased with the increase of suction pressure and with decrease of picker end diameter. Maximum trash content of 5.64 % was achieved at 40 mm of picker end diameter with suction pressure of 30 mm of Hg. Minimum trash content of 0.65 % was achieved at 20 mm picker end diameter with suction pressure of 30 mm of Hg.
3. The output capacity increased with the increase of suction pressure and with decrease of picker end diameter. Maximum output capacity of 6.25 kg/h was achieved at 25 mm picker end diameter with suction pressure of 45 mm of Hg. Minimum output capacity of 2.51 kg/h was achieved at 40 mm of picker end diameter with suction pressure of 15 mm of Hg.
4. Picker end diameter and suction pressure affected the output capacity, trash content and picking efficiency significantly at the 5 % level. Effect of interaction of both the factors was significant at the 5 % level for output capacity and trash content but was non significant at the 5 % level for picking efficiency.

Table 5 Effect of suction pressures on picking efficiency, trash content and output capacity with 25 mm picker end diameter for different stages of picking

Suction pressure, mm of Hg	Picking efficiency, %	Trash content, %	Output capacity, kg/h
First stage of picking			
35	93.90	5.70	4.20
40	94.72	6.90	4.47
45	95.90	7.50	4.72
50	97.20	8.30	5.31
Second stage of picking			
35	92.80	4.39	4.01
40	93.97	5.81	4.27
45	94.70	6.60	4.50
50	96.60	7.23	5.12

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Status of Maize Threshing in India

by

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Abstract

In India, maize is emerging as the third most important crop after rice and wheat, and it has significance as a source of a large number of industrial products besides its use as human food and animal feed. Maize is also a versatile crop, allowing it to grow across a range of agro-ecological zones. Every part of maize has economic value as the grain, leaves, main crop stalk, tassel and cob can all be used to produce a large variety of food and non-food products. In India maize is grown in all the seasons, i.e., kharif, rabi and summer. After harvesting with sickle and plucking of cob manually, dehusking of cob is done by hand to remove its outer sheath and further grain is obtained by shelling the cob traditionally, i.e., by beating the dehusked cobs with sticks or with fingers or sickle, etc. This activity is mostly done by farm women. The output in terms of dehusking-shelling maize cobs was reported to be 30 kg/h with 8.3 percent grain damage in the traditional system (dehusking by hand and shelling by beating wooden sticks). From a random sample of 200 undehusked dry cobs, the minimum and maximum lengths were found to be 160 and 265 mm with varied maximum diameter of 36 to 52 mm. The equipment for shelling has been developed and commercialized. For dehusking-shelling maize cobs, power operated equipment has been developed and are being commercialized. This equipment may be suitable for an economically strong group of farmers (medium and large farmers) while in the country, about 80.3 percent of farmers of marginal and small size groups operate 36 percent of the area. In the paper, design considerations for developing a hand operated maize dehusker-sheller are given that can be utilized for developing equipment suitable for women workers.

Introduction

Globally, maize (Zea mays L.) is grown in more than 146 million ha with production of about 700 million tonnes in 2006-07 (Anonymous, 2008a). USA has 30 percent of the total global maize production (**Fig. 1**) while other major maize producers are China (15 percent), European Union-25 (14 percent), Brazil (4 percent) and India (3 percent).

In India, maize is emerging as the third most important crop after rice and wheat. Among the maize producing states, Andhra Pradesh tops the list with a contribution of 17 percent (**Fig. 2**) followed by Rajasthan (14 percent), Madhya Pradesh (12 percent), Bihar (10 percent), Uttar Pradesh (9 percent), Karnataka (8 percent) and Gujrat (6 percent). Maize was grown in about 7.5 million ha during 2006-07 with a yield of about 1.88 t/ha. The area under maize cultivation and its yield was 2.34 and 3.43 times more in 2006-07 as compared to 1950-51 (**Fig. 3**). Among cereals, maize ranks 5th in area and 3rd in total production after rice and wheat (Anonymous, 2006a).

Maize has its significance as a source of a large number of industrial products besides its use as human food and animal feed. It is the major food and an important source of income for marginal and small farming communities in many of the countries, particularly maize producing states. Some diversified uses of maize are for alcoholic beverage, maize corn, starch industry, corn oil production, baby corns and popcorn. Potential for exports has added to the demand for maize all over the world. Maize does possess tremendous potential in terms of feed for dairy, poultry and piggery agro-industries.

Maize is also a versatile crop, allowing it to grow across a range of agro-ecological zones. Every part of maize has economic value as the grain, leaves, main crop stalk, tassel and cob can all be used to produce a large variety of food and non-food products. In India maize is grown in all the seasons, i.e., Kharif, Rabi and summer. Of these three seasons, nearly 90 percent of the production is from Kharif season, 7-8 percent during Rabi season and remaining 1-2 percent during summer season. Presently, in India, maize is mainly used for preparation of poultry feed (nearly 75 percent) and extraction of starch (20 percent). Low protein maize along with other cereals constitutes major dietary intake of the poor population of India.

Traditional Practices for Dehusking-Shelling Maize Cob

Maize crop sown for grain is harvested when it reaches physiological maturity and contains 25-30 percent moisture (Anon., 2006a). Cob is plucked by hand either from standing plant or harvested plant. Mostly, harvesting of maize crop is done manually with a traditional sickle. After that, cobs are dried in the sunshine to reduce moisture content to 15-21 percent (d.b). Different parts of plucked cob (un-dehusked) are shown in **Fig. 4**. Dehusking of cob is done by hand by removing the outer sheath and grain is obtained from the dehusked cob (the process is called shelling). Traditional practice followed in the country for obtaining grain from dehusked cobs is either by beating the dehusked cobs with sticks or with fingers or a sickle. Various researchers quoted

Fig. 1 Share of major maize producing countries
Source: Anon., 2008a

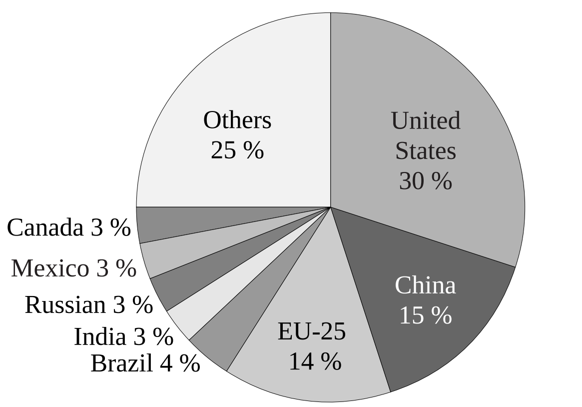


Fig. 2 Share of major maize producing states in India
Source: Anon., 2008a

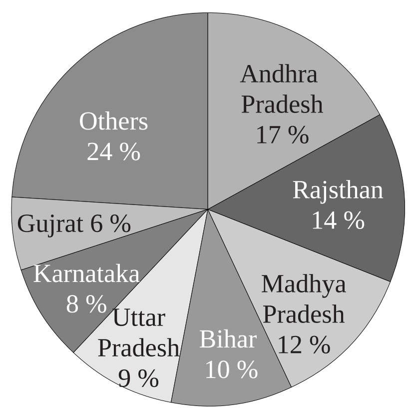


Fig. 3 Area, Production and yield of maize in India
Source: Anon., 2008a

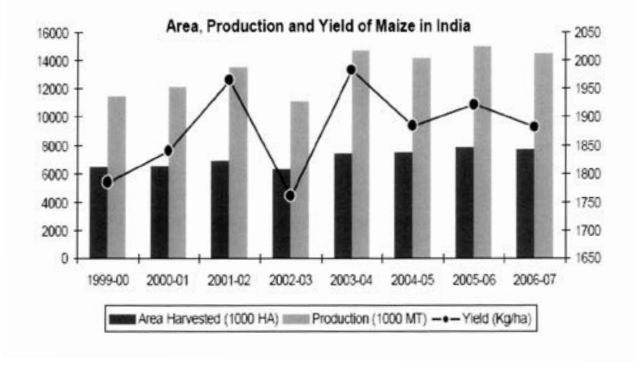
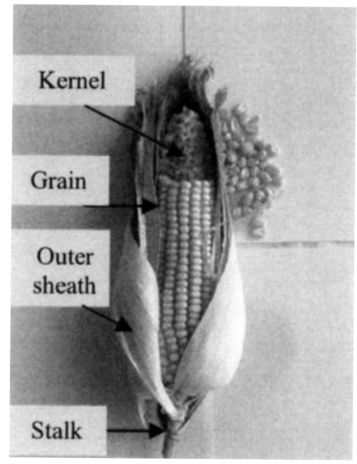


Fig. 4 Different parts of plucked maize cobs



the output with this system (**Table 1**). The output was reported to be 30 kg/h with 8.3 percent grain damage while cobs were dehusked by hand and grain was obtained by beating the dehusked cobs with wooden sticks. It is also reported that the percent recovery of grain from the maize cob in manual shelling was only 78.4 percent (Anon., 2005a). Thus, this operation is highly labour intensive and full of drudgery in addition to losses in quality and quantity. Though, now a few manufacturers of Punjab state of the country are trying to make a header unit for harvesting the maize crop.

Farm women are involved mostly for these operations. The average size of operational land holdings by major groups such as marginal, small, semi-medium, medium and large are 0.4 ha, 1.42 ha, 2.73 ha, 5.84 ha and 17.21 ha, respectively, with average national holdings of 1.41 ha, (Anon., 2004). About 80.3 percent farmers of marginal and small size groups operate 36 percent of the area. Of this, 76.7 percent of farmers are in the marginal group. It is also important to emphasize that most of the agricultural workers belong to this group. It has been reported that agriculture is a major source for employment of farm women, which is 87 percent of the total 496 million female workers as per the 2001 census (Anonymous, 2008b). The population statistics of men and women workers in agriculture since 1951 and their estimated population in 2007, 2012 and 2025 are given in **Table 2**. These statistics forced the researchers and policy planners to give more emphasis to developing improved equipment suitable for farm women. Rahman (1993) also emphasized that greater efforts must be made to target women and more equipment must be developed for female use, since it is they who do the majority of farm work.

Table 1 Output capacity of dehusking, shelling and dehusking-shelling maize cobs*

Traditional Methods	Output capacity, kg/h
Shelling of cob using sickle	17.1
Shelling of cob using back side of sickle	4.5
Shelling of cob by beating with a wooden stick	40 (8.3% grain damage)
Dehusking the cob	25 to 35 (cobs)
Dehusking the cob by hand and shelling by beating with wooden sticks	30 (8.3% grain damage)
Shelling of the cob by beating	15.2
Shelling of the cob with finger	5.2

*Source: Singh *et al*,, 2007; Kumar and Parvathi, 1998; Ali *et al*, 1986; Anon., 1980 and Anon., 1981 a, Vatsa *et al*., 2007 and Vatsa and Singh, 1998.

Table 2 Population dynamics of agricultural workers in India

Census Year	Population Dynamics of Indian Agricultural Workers, million*			
	Men	Women	Share of women workers, %	Total
1951	66.14	31.06	31.95	97.20
1961	83.83	47.27	36.06	131.10
1971	100.24	25.46	20.25	125.70
1981	112.30	35.7	24.12	148.00
1991	133.60	51.7	27.90	185.30
2001	142.75	91.34	39.02	234.09
2007**	140.00	101	41.91	241.00
2012**	132.00	109	45.23	241.00
2025**	109.00	133	54.96	242.00

* Source: Anon., 1974; Anon., 1981b; Anon., 1991 and Anon., 2001.
** Anon., 2006b.

Table 3 Physical properties of dry maize cob and grain

Variety: JM 216

Particulars	Details/Mean (S.D) Value	
	Un-dehusked Cob	Dehusked Cob
Cobs having stalk, %	91.5	-
Cobs do not have full grain over cob length, %	-	85.5
Maximum diameter, mm	53.1 ± 4.1 (43-66)	45.4 ± 3.2 (36-52)
Total length, mm	210.3 ± 22.7 (160-265)	174.4 + 21.4 (95-230)
Weight, g	178 ± 31.1	
1,000 grain weight	-	269.3 g
Number of grain lines	-	14 - 15 ± 2 (10-18)
No. of grains/line of cob having full grain in length	-	36 ± 7
Grain size (l × b × t), mm	-	10.34 ± 0.67 × 8.48 ± 0.81 × 4.26 ± 0.6

Note: Ranges are given in parenthesis.

Physical Properties of Un-Dehusked Cob, Dehusked Cob and Grain

Data on physical properties of JM 216 variety of dry cobs (un-dehusked and dehusked cobs) were collected for getting base data in terms of number of cobs (with and without attached stalk with cobs during plucking from plant)., correspondingly its length, weight of un-dehusked cobs & maximum diameter of cobs., number of grain lines in dehusked cobs., grains per dehusked cob and 1,000 grain weight and grain size (**Table 3**). Randomly, 200 un-dehusked cobs were taken for this study. On the average, 91.5 % un-dehusked cobs had attached stalk of 40.3 + 24.2

mm in length and 10.9 + 2.0 mm in diameter. Mean total length of un-dehusked cobs was 210.3 + 22.7 mm with average maximum diameter of 53.1 + 4.1 mm. Average weight of un-dehusked cobs was 178 + 31.1 g. The 1,000 grain weight of dry cob was 269.3 g. About 85.5 percent dehusked cobs do not have grain up to its full length. On an average, 14-15 grain lines were observed in each cob with 36 + 7 grains in each line having size of 10.34 + 0.67 mm in length, 8.48 + 0.81 mm breadth and 4.26 + 0.6 mm thickness. Mudgal *et al.* (1998) reported that the porosity, bulk density, angle of repose, specific gravity and thermal conductivity of Ganga-5 and Malan varieties varied from 38 to 47 percent, 0.773 to 0.739 g/cc, 28.6 to 32.70 and from 36.4 to 42.7 Cal/cm-sec-ºC × 10^{-5}, respectively, where moisture content varied from 8 to 20 percent.

Improved Farm Equipment for Maize Dehusking and Dehusking-Shelling and their Status

For shelling of maize cobs, manual/ hand (octagonal tubular maize sheller, hand maize sheller and rotary maize sheller) and power operated maize shellers have been developed and commercialized. It was reported by Singh (2008a) that tillage, sowing/planting and weeding operations for maize cultivation was mechanized by 80-90 percent, whereas level of mechanization in harvesting and threshing was below 20 percent.

Maize being a major crop grown in both the agricultural seasons, i.e., Kharif (June-September) and Rabi (November to March). Work was started at MPUAT, Udaipur in 1970 on farm equipment for dehusking, shelling and dehusking-shelling. Mudgal *et al.* (1998) reported the development of the following equipment related to dehusking and dehusking-shelling:

1. Hand operated maize dehusker
2. Pedal operated maize dehusker
3. Pedal operated maize dehusker-cum-sheller
4. Pedal operated maize dehusker-sheller
5. Power operated maize dehusker
6. Power operated maize dehusker-sheller

For making a dehusker, a pair of rubber and steel rollers was used

Fig. 5 Maize Dehusker (MPUAT, Udaipur)

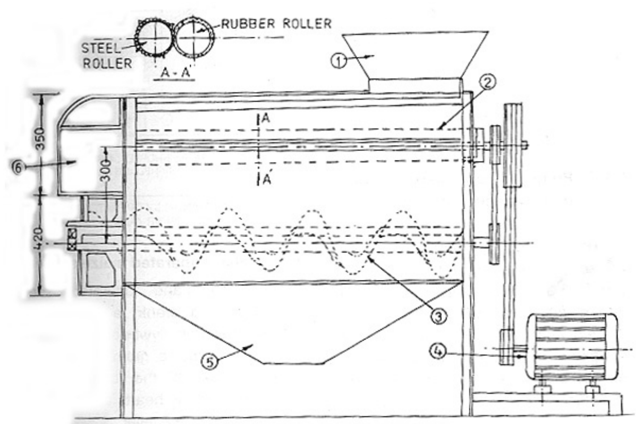
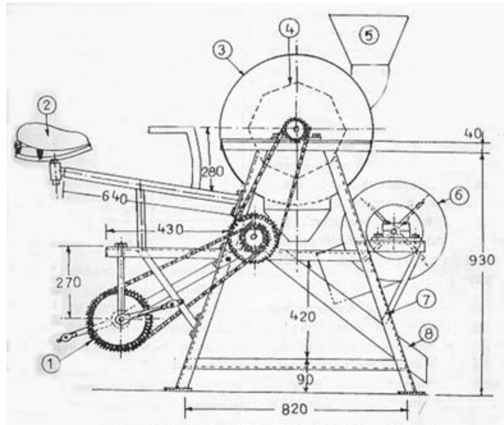


Fig 6 Pedal operated Maize Dehusker-sheller (MPUAT, Udaipur)



1-Chain sprocket, 2-Seat, 3-Cover, 4-Dehusking cylinder, 5-Hopper, 6-Blower, 7-Stand/Frame, 8-Tray

Fig 7 TNAU Maize Dehusker-sheller

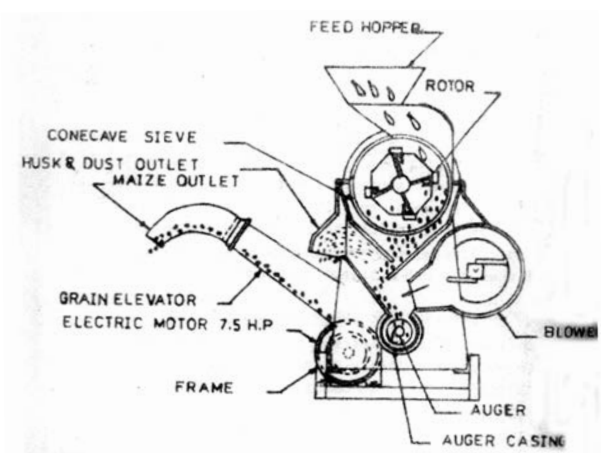
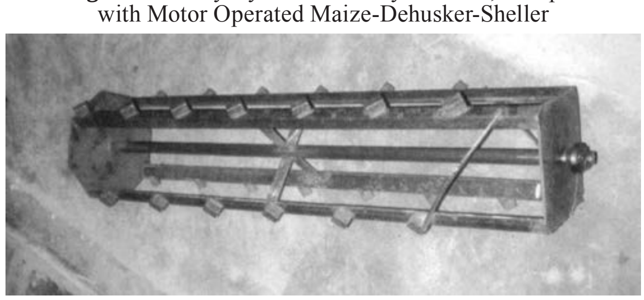


Fig. 8 Presently Cylinder Used by MPUAT, Udaipur with Motor Operated Maize-Dehusker-Sheller



with opposite rotation of each roller (**Fig. 5**). MS rod was also tried by welding spirally for this purpose on a steel roller. Some serrated blades were used lengthwise to facilitate the dehusking. For making a dehusker-cum-sheller, in addition to the above, a wooden cylinder with rubber strips along its length on the periphery was used for shelling. A combined unit for dehusking-shelling in one cylinder was tried by using half of the cylinder length with rasp bars and the other with rubber strips on an octagonal cylinder to act as dehusker and sheller, respectively (**Fig. 6**). In a power operated maize dehusker-sheller, in addition to the above, helical louverers were provided for easy passage of the dehusked cob after shelling from the cylinder.

TNAU, Coimbatore has also worked on a maize dehusker-sheller for removing the outer sheath and for shelling the maize cob simultaneously (Anon., 1986). The machine has lugs (square solid blocks) on the dehusker-sheller cylinder with louverers (helically) at the start and end of the cylinder (**Fig. 7**). This cylinder arrangement for dehusking-shelling has been adopted by a few farm machinery manufacturers as it is seen in one of commercial power operated units. Presently, lugs have also been incorporated by MPUAT, Udaipur in their power operated maize dehusker-sheller (**Fig. 8**).

MPUAT, Udaipur has also developed a 5.5 kW motor operated whole crop maize thresher (Singh, 2008b). Development of this machine was to dehusk and shell the maize cob and simultaneously convert the stalk to chaff. A spike tooth cylinder with 6-7 bolts per row on the periphery was used and a concave was prepared by 8 mm square bars at a spacing of 18 mm. The threshing speed was 620 rpm and output of the machine was 210 kg/h. Maize stalks, after detachment of the cob, were used for animal feed but only 30 percent of the main crop stalk was consumed. A tractor operated multi-crop thresher was also modified with similar arrangement and grain output was 640 kg/h with chaff size of 18 to 52 mm (**Fig. 9**).

PAU, Ludhiana modified a spike tooth wheat thresher and axial flow sunflower thresher to dehusking-shelling of maize cobs (Singh and Pandey, 2008). In the axial flow thresher, pegs were mounted on a cylinder in a helical pattern to form an auger for the movement of crop in 12.7 cm/turn. The concave clearance was 50 mm. An upper concave was provided in the first 1/3rd length of the threshing cylinder as a dehusking zone. The average material capacity of the axial flow thresher was 18 q/h while the output with modified wheat thresher was 4 to 5 q/h. The equipment (axial flow modified thresher) has been commercialized (**Fig. 10**).

Status of maize dehusker and maize dehusker-shellers, including commercial designs, are given in **Table 4**. The power operated maize dehusker-sheller is now being commercialized and is being adopted by large farmers (economically sound) and is also being used on custom-hiring.

As seen from statistical data regarding operational holdings and farmers, there is a need to develop dehusker-sheller that can be operated by one or two persons. Earlier, a pedal operated dehusker and dehusker-sheller were developed that was operated by two men workers. However the equipment could not be neither commercialized nor adopted by the farmers. This might have been due to human operator-related factors such as age, gender, strength, body size, technique, experience and posture and equipment factors such as type, grip/handle shape and size, wrist orientation, reach distance, force/torque requirement of the task and duration of application of force/torque, in addition to an old design. Moreover, development of equipment for dehusking-shelling maize cobs was basically for men workers though the dehusking and shelling of maize cobs are mostly done by farm women. It was also reported that farm women were not accustomed with cycling, may be due to wearing loose cloth (Sarhi),

Fig. 9 MPUAT Design Whole Crop Maize Dehusker-Sheller

Fig. 10 PAU Design Axial Flow maize Dehusker-Sheller

(Anon., 2005b and Singh, 2005). It was also reported that agriculture was a major source for employment of farm women (87 % of total were female workers). There were and 127.22 million total workers out of 496 million total women population as per the 2001 census (Anon., 2008b).

From the above, it is clear that no hand operated maize dehusker-sheller is available. A hand operated maize dehusker-sheller is also needed for hill and plain farmers having less area under maize. This may also be useful for other categories of farmers as the supply of electricity in the villages is uncertain and erratic and farmers are forced to search for other options.

Hence, it would be more practical if the equipment were designed/ developed for women workers since, in most of the cases, the equipment (dehusker-sheller) suitable for women workers will automatically suit men workers because ergonomic characteristics of women workers (like, aerobic capacity, muscular strength and anthropometrical dimensions) are less than those of men workers (Gite and Singh, 1997; Singh *et al*., 2006; and Singh *et al*., 2008). Shelling of the cob is comparatively easy to achieve by sharp rubbing actions or striking

Table 4 Status of maize dehusker, maize dehusker-shellers in India*

Equipment	Design/ Make	Power source	Cylinder size, mm	Beater size (L × T × W), mm	Type of threshing element	Peripheral speed, m/s	Dehusking-Shelling efficiency, %	Output capacity, kg/h
Pedal operated maize dehusker sheller	MPUAT, Udaipur	Two men	450 × 1,000	-	Half rasp bar & other with rubber strip	5.5 to 6	95	225
Pedal operated maize dehusker cum sheller		One men	400 × 400	8 nos. of 50 × 20 mm rubber strip	Two steel roller & Wooden cylinder for shelling unit	5 to 5.5 (225 to 250 rpm)	90.0 & 95.4	130
Axial flow maize dehusker-sheller		5 hp	376 × 1,050	30 × 30 × 50	Solid lugs	5.5 to 6.5 m/s	98-99	800
Multi-crop thresher	CIAE, Bhopal	5 hp motor	500 × 584	80 × 8 × 25 Flat	Spike tooth type	8.4	99.9	1,635**
Semi axial flow multi crop thresher		7.5 hp	540 × 740	16 × 80 Stud	Spike tooth type		99.8	1,350**
High capacity multi crop thresher		20 hp motor/ 35 hp tractor	700 × 1,100	180 × 10 × 40 Flat	Spike tooth type		100	2,900**
Axial flow maize dehusker-sheller	PAU Ludhiana / Amar	35 hp tractor	480 × 325	50	Spike tooth	16.4	97-98	450-650
		35 hp tractor	495 × 1,460	50	Peg type	13.7	96-98	1,690-2,050
Axial flow Maize thresher	TNAU, Coim-batore	10 hp	-	-	Solid Lugs	-	-	1,500-2,000
Husker sheller thresher for maize/ corn	Vidhata	Tractor PTO 15 hp	-	-	-	-	98.0 % 85 dry corn	2,000-2,500 kg grain
Maize corn thresher	Vidhata	Tractor PTO	-	-	-	-	-	5,000 at 85 % dry corn
		5 hp	-	-	-	-	-	2,000
Maize dehusker-sheller	PAU design	Power tiller	330 × 1,200	Pegs of 25 × 25 × 40 (44 nos.)	Peg tooth with concave clearance of 60 mm	10.71	97.2 %	1,290 at 15.8 % d.b.
Whole plant maize thresher	MPUAT Udaipur	Motor 5.5 kW	-	6-7 bolts/ row	Spike tooth with concave having 8 mm sq. bar	620 rpm	100.0	210 at 12.2 % m.c
		Tractor	-				100.0	640 at 13.4 % m.c

*Source:
Pandey *et al*., 1997; Anon., 2005a, Singh, 2008b, Vatsa *et al*., 2007 and website http://www.asianpowercyclopes.com/, http://www.vidhataindia.com, www.fourbrothersei.com / www.bossmachines.in, http://agricoop.nic.in/dacdivision/Machinery1/chap5b.pdf on 8.12.2008 at 3.24 pm
** For dehusked cob.

out and, for this, a short cylindrical cage may be adequate. Thus, an attempt is being made to get some of the parameters that may be helpful in designing a hand operated maize dehusker-sheller suitable for farm women.

Design Considerations for Developing a Hand Operated Maize Dehusker-Sheller for Farm Women

Based on review of literature and theoretical considerations, the following concerns have been identified for the design of a hand operated maize dehusker-sheller for farm women:

- There is need to know the maximum power available with women workers. For example, based on preliminary trials on "Torque generated by farm women for 30 min duration at 50 rpm", the maximum power available with women workers was estimated to be about 100 W.
- There is also need to know the power available for only dehusking-shelling the maize cobs out of the maximum available power. For example: the power available for dehusking-shelling the maize cob was about 76 W (5 % loss due to chain-sprocket, 10 % in stepping up and 9 W power loss to overcome idle resistance).
- After determining the power, the type of threshing system may be selected based on available power and requirement. For example: The axial flow system could be adopted for hand operated maize dehusking-shelling, as it consumes less energy because it does not make fine straw in comparison to spike tooth and rasp bar type threshers. Moreover, with dehusker-sheller, there is no need of making straw. It will also help in providing retention time for un-dehusked cobs to be dehusked and shelled.
- Of the rasp bar, spike tooth and square solid lugs, solid lugs can be used as threshing element on MS angle iron beater it also helps in reducing the energy requirement in the operation of dehusking-shelling the un-dehusked cobs due to less contact with cob.
- Number of solid lugs in each beater could be three to four for hand operated maize dehusker-sheller depending on maximum and minimum size of cob. The spacing between lugs on beater should be decided in such a way that the smallest cob could be dehusked and shelled. Based on data given in the paper, the spacing may be about 80 mm.
- Number of beaters in a threshing cylinder could be four up to threshing cylinder diameter of 400 mm. This may avoid easy wrapping of un-dehusked cobs with threshing members as beaters will be fixed at equal spacing.
- Concave clearance may be 40-50 mm.
- Two helical louvers (one at the feeding side and the other at the outlet side) may be provided on the cylinder for easy movement of un-dehusked and dehusked cobs.
- The cylinder length could be determined based on maximum length of un-dehusked cobs. The length of cylinder should be about 2.5 times the maximum length of cobs to get proper retention time at the feed rate of less than 100 kg/h for dehusking-shelling with the equipment.
- Feed hopper may be designed in such a way that the feeding should not be more than 10 percent of design value to avoid over feeding which may affect the performance of the equipment.
- Peripheral speed for hand operated maize dehusker-sheller could be around 5 to 5.5 m/s.
- Hand cranking at 50 rpm could be considered appropriate and, accordingly, speed may be stepped up.
- The limited power could be utilized for dehusking-shelling the cob with the equipment by controlling feed rate (manually).
- The handle height of equipment may be kept at metacarpal-III height during downward position and it should be below the shoulder height at upward position. As per design requirement, this space may be the criteria for deciding crank length of handle depending on torque/load at given feed rate.

Conclusions

Power operated maize dehusker-sheller/threshers for dehusking-shelling maize cobs have been developed and are being commercialized. Hand operated maize dehusker-shellers are not available as they are required for hill, marginal and small farmers. Since, traditionally, the dehusking-shelling of maize cobs is being done mostly by farm women an attempt has been made to consider the appropriate parameters in developing a hand operated maize dehusker-sheller.

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NEWS

A Mechanical Flame Unit for Soil Pest Control

by
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Abstract

Pests control is one of the most expensive operations in crop production. At the same time, pesticides have an effective role in environmental pollution. Therefore, an attempt was made to develop a simple flame unit that could be fitted on the frame of a chisel plow during secondary tillage by pushing the flame on and under the soil for burning all pests in their different phases and preserve the environment. The new system was developed, tested and evaluated at farms of the faculty of Agriculture Mansoura University on a soil of 35.7 % silt, 47.1 % clay and 17.2 % sand.

The effect of flame unit parameters (tractor speed, space between beams and flaming depth) were studied. The experimental data showed that the developed unit had good technical characteristics. All nematodes died and the highest effect on weeds was at 0.25 m space between beams, 0.05 m flaming depth and the first level of forward speed (1.54 km/h).

Introduction

Mechanization to apply push flame under the soil for pest control was limited until now. So, it may be considered that the development of a simple system for push flame under the soil that has optimum performance, good reliability, suitable for the environment and is economical represents a major stage towards using mechanization to keep the environmental pollution low and decrease agricultural production cost.

The concise oxford dictionary defines a pest as a troublesome or destructive person, animal or thing,

NOTATIONS

W	Width between beams, m	S.W.	Specific weight of kerosene, kg/m^3	a	Life expecting of the machine, year
V	Forward speed (velocity), km/hr	hu	Upper blowpipe height, m	i	Interest % from the cost of machine work, %
D	Flaming depth, m.	R	Upper blowpipe tilt angle, º	t	Taxes % from the cost of machine, %
Q	Fuel consumption, L/hr	Y	Flame exit angle from upper blowpipe, º	r	Repair and maintenance % from the cost, %
Cd	Discharge coefficient	Z	Upper blowpipe's flame angle with soil surface, m	w	Power, h.p.
Cv	Velocity coefficient	L	Flame width on the soil surface, m	s	Specific fuel consumption, L.E/hp.hr
Cc	Contraction coefficient	M	Flame tilt line length, m	f	Fuel price, L.E.
A	Area of outlet opening, m^2	O	Flame overlapping, m	m	Operator monthly salary, L.E.
c	Diameter of outlet opening, m	α	Loss percentage of nematodes	μk	Viscosity of kerosene (kinematics), Ml^{-1} T^{-1}
g	Standard gravitation, m/sec^2	γ	Controlled weeds percentage	s.t	Surface tension of kerosene, MT^{-2}
H	Head of kerosene, m	M.C.	Moisture content, %	ρk	Density of kerosene, ML^{-3}
ΔP	Average of pressure, kg_f/m^2	h	Working hour, hr/year	P	Pressure inside tank, kg_f/cm^2

Kumar (1984).

Matthews (1984) showed that there are several ways to use temperature to control soil borne pathogens. The most common and effective way is raising the temperature to or above the thermal death point of the organisms. In a soil medium this is accomplished by steam heat (free-flowing or under pressure), by electrical heat by burning combustible material on the soil surface or by solar radiation. When the pathogen is present in or on a seed, tuber, bulb, or rhizome, it is sometimes possible to raise the temperature of the propagate organ sufficiently hot. Eradication of the pathogen is, thus, accomplished.

Ibrahim (1985) showed that combined results of previous survey studies have shown that root knot nematodes (RKN) were of widespread occurrence and were becoming an aerial threat to agriculture in certain localities of Egypt. He added, also, that nematodes infestation and attack on agricultural crops reduced growth, yields and quality of the produced crops and, consequently, decreased the commercial value of crops, thus, substantially affecting the national economy.

Islam (1990) showed that excess in using pesticides lead to loss of natural-balance between the pests and natural enemies, excess of some pests such as spider mites and spiny boll-worms due to killing their natural enemies. And so, the sparrow is threatened with extinction. The cattle and some mammals have been affected by pesticides in one way or another. Also, it is poisonous to bees, fish, birds, sea and lakes animals and river water.

EL-Nakib (1990) showed that flame is more efficient (98-100 %) with grasses. Flame is preferable with grass than mechanical methods because mechanical cultivators diffuse the rhizome (stock root) in soil.

Abdel-Latif (1992) showed that weeds compete with the crop for nutrients, water and sunlight. They re-infest the field when allowed to produce seeds; furthermore, such weeds may interfere with harvesting equipment and cause a decrease in yield and harvesting efficiency.

Sewify and Herakly (1993) showed that, in Egypt, weeds are reported as important hosts for several species of leafhopper, some species of these leafhoppers are known as vectors of viral and mycoplasma like disease agents to several important crops.

Salim (1996) designed a flame unit for soil pest control by inserting the flames of fire into the soil using special designed nozzles fixed on chisel plow beams to meet the demands of the Egyptian farmers for cheaper and more appropriate technology for the soil pest control without environmental pollution. Also, he added that, pushing the flame under soil during secondary tillage was more efficient with nematodes and weeds and the efficiency reached to 100 % and 95.4 %, respectively.

El-Danasory (2000) tested a flame weeder at different forward speeds and angle and height of burner under various conditions of growing weeds. The highest efficiency of the flame weeder was obtain at a height of flame that ranged from 3 to 6 cm and an angle from 0 to 20 degrees.

Flame Characteristics

A preliminary test was conducted to test the design of the flame parameters such as the pressure inside the fuel tank, the head affected the fuel discharge and the flaming pipes positions and their dimensions.

Upper blowpipe:

Kerosene pressure: The pressure of kerosene can be changed by the kerosene regulator valve and produces:

1. Change in Flame Intensity

2. Change in Fuel Rate (Fuel Consumption) that can be Calculated as Follows:

The fuel velocity and the fuel consumption would be calculated theoretically according to Gieek (1979).

$$Q = Cd \times a \times \sqrt{2g(H + \frac{\Delta P}{S.W.})}$$

$$Cd = Cv \times Cc$$

$$a = \frac{\pi d^2}{4} \text{ and } V = Cv\sqrt{2gH + \frac{\Delta P}{S.W.}}$$

where:

Q	Fuel consumption	L/hr.
Cd	Discharge coefficient	0.496
Cv	Velocity coefficient	0.80
Cc	Contraction coefficient	0.62
a	Area of outlet opening	m^2
d	Diameter of outlet opening	0.55 m
g	Standard gravitation	m/sec^2
H	Head of kerosene	m
Δ P	Rate of change in pressure	kg_f/m^2
S.W.	Specific weight of kerosene,	kg/m^3

$$Cd = Cv \times Cc = 0.80 \times 0.62 = 0.496$$

$$a = \frac{\pi d^2}{4} = \frac{3.14 \times (0.55)^2}{4} = 0.238\ cm^2$$

$$= 2.38 \times 10^{-5}\ m^2$$

$$\because \Delta P = 0 \quad \therefore V = Cv\sqrt{2gH}$$

$$\therefore V = 0.80\sqrt{2 \times 9.81 \times 0.10}$$

$$= 1.12\ m/sec.$$

$\therefore$ *Qth. = 0.496 × 2.38 × 10-5 × 1.40 = 1.65 × 10-5 m^3/sec.*

$\therefore$ Fuel consumption is 0.059.42 m^3/hr = 59.52 L/hr.

The rate of discharge can be calculated experimentally as follows:

19 liter ⟶ 19 min.

x ⟶ 60 min.

$$\therefore x = \frac{19 \times 60}{19} = 60\ L/hr.$$

3. Flame Angle:

The angle of flame axle was constant during the experiments at 40° with the horizontal. Smith (1965) recommended that a suitable flame angle should be at 30º-40º with horizontal.

4. Flame Heights:

Flame height measured as the vertical height from the nozzle to the soil surface. The experiments were conducted at 0.13 m. height.

5. Flame Width:

Flame width was measured in the

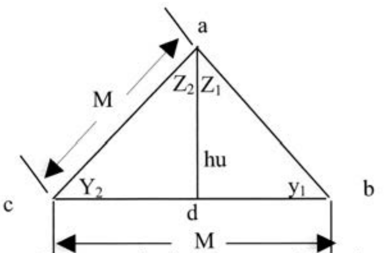
field at constant flame height and flame pressure. It was 0.45 m in the conditions of experiment.

6. Flame Overlapping:

The flame overlapping depended on the flame pressure, its height, evaporate pipe length, width between beams and flame width on the soil surface. It was easy to see that the overlapping was indirectly proportional to the width between beams where:

Overlapping = flame width − width between beams.

O = L − W



Flame section in one upper blowpipe

where:

$Sin\ z1 = bd/ab$ .... (1)

$\therefore\ bd = ab\ sin\ 60$ .... (2)

$Sin\ z2 = cd/ac$ .... (3)

$\therefore\ cd = ac\ sin\ 60$ .... (4)

.. $bd = cd\ \&\ z1 = z2$

and $bd + cd = cb$

$\therefore\ cb = 2\ (ab\ sin\ 60) = 2\ (ac\ sin\ 60).$

$sin\ 60 = \frac{\sqrt{3}}{2}$

$\therefore\ cb = 2\ ab \times \frac{\sqrt{3}}{2} = \sqrt{3}\ ab$

$\therefore\ cb = \sqrt{3}\,ac = \sqrt{3}\ M$

$\therefore\ L = \sqrt{3}\ M$

.. $tan\ 30 = ad / bd = ad / cd$

$\therefore bd = cd = ad / tan\ 30$

$tan\ 30 = 1 / \sqrt{3}$

.. $cb = bd + cd = 2\ ad/tan\ 30$

.. $hu = ad$ and .. $L = cb$

$\therefore\ L = 3.464\ hu$

.. $y = 30^o$

$\therefore\ hu = 0.5\ M$

The following equations describe the relationship among O, L, W, hu, M, sin y and cos z (as observed in the range and conditions of experiment).

1. O = L − W
2. L = $\sqrt{3}$ M
3. L = 3.464 hu
4. hu = 1/2 M
5. sin y = cos z = $\sqrt{3}$hu/L = hu/M

Lower Blowpipes:

A series of preliminary tests were carried out to determine the best heights between lower blowpipe nozzles and the soil surface. It was found that 0.175 m was the best height while the throat outlet flame was 0.075 m under the soil surface. As the nozzle was above the soil surface, it required the necessary oxygen to flame.

Materials and Methods

Equipment:

The developed flame unit consisted of the following parts as shown in **Fig. 1**.

1. Kerosene Drum (Tank):

A cylindrical tank with 0.20 m diameter and 0.65 m length was fixed horizontally on the chisel plow (Ramsson) frame. The following parts were fixed on this tank:

(1) Manual compressor:
The manual compressor consisted of an axle made of galvanized steel 0.50 m. long provided with a wooden handle in the front. A spring was put on the axle and a bluff was fixed at extend of the spring. It provided the tank with air which pushed the kerosene inside the pipes under pressure. Also, steering was done manually.

(2) Inlet opening of 0.02 m diameter was provided with a cap and was used to fill the tank with kerosene.

(3) Manometer: used to measure the pressure inside the kerosene tank. The pressure range during all experiments was adjusted at 1-1.5 kg/cm^2.

(4) Outlet opening: for supplying the kerosene in main feeder line.

(5) Main valve: It used to change the flow rate of kerosene to six blow pipes.

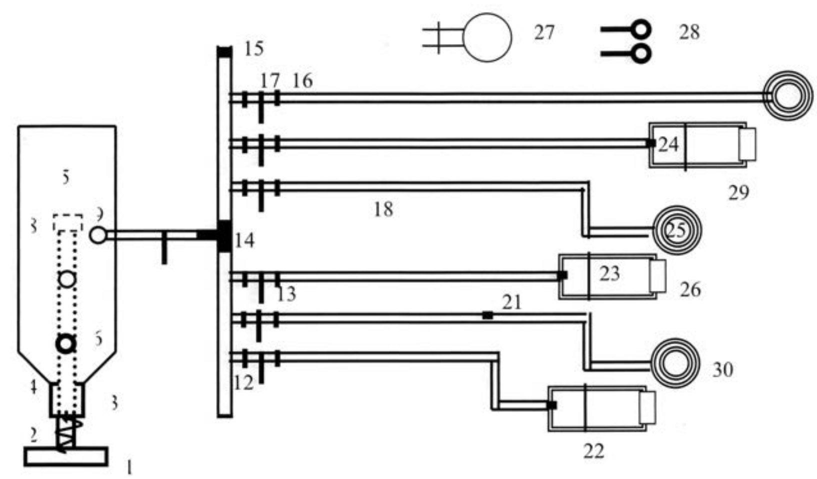
(6) Distributor: for supplying kerosene in sub main lines.

(7) Regulator valves: To control flow of kerosene in each pipe separately.

(8) Feeder lines: These pipes connected the hoses with the blowpipes.

(9) Blowpipes: The nozzle was fixed in the front to push the flame inside the chamber which is hot, and then it evaporates the kerosene. Six blowpipes were fixed on the beams two blowpipes for every

Fig. 1 Plan view of the developed flame unit



1- Handle, 2- Spring, 3- Axle, 4- Fixed nut. 5- Tank, 6- Fuel hole, 7-Manometer, 8- Bluff., 9- Out put hole, 10- Main value, 11- Distributor, 12- Copper socket, 13- Plug, 14- Tees, 15- Reserve socket, 16- Clips, 17- Kerosene regulator value, 18- Rubber hose with thermal wire, 19- Pipe, 20- Elbow, 21- Socket, 22- out chamber, 23- Evaporate pipe, 24- Nozzle, 25- inside chamber, 26- Throat, 27- Fixed tin, 28- Fixed screws, 29- Upper blowpipe, 30- Lower blowpipe.

beam fixed one above the other.

2. Tractor and Chisel Plow:

A 60 hp (44.77 kW) Nasr tractor and a 9 Ramsson chisel plow body was used in this study.

Experimental Design

As previously mentioned, there were three main treatments for controlling efficiency at 0.25, 0.30 and 0.35 m, respectively. The three treatments were conducted in a trial laid out in split split plot design with three replicates. Each main plot was divided into three sub-plots 3 × 40 m and every sub-plot divided into three sub-sub-plots. The three treatments were randomly distributed on every sub-plot; one treatment on each sub-sub-plot.

Analysis of variance (ANOVA) was done for each depth in the separate experiments to compare the difference between means of width between beams, forward speed and interaction between them of the developed flame unit. The analysis of variance and also the least significant differences between means at the significance levels (5 % and 1 %) were adopted from the M-STAT program according to ***Gomez (1984***).

Measurements:

The random samples of soil were taken from each experimental sub-sub plots (30 sub-sub plots) at a depth 0.05, 0.10 and 0.15 m, respectively, in all stages to determine the following measurements:

1. Nematodes/250 gm. soil

Ninety random samples of soil were taken from each experimental sub-sub plots to extract the number of nematodes in 250 gm soil by using the nematode filter method and electric microscope to number them. These were conducted in the laboratories of the Agricultural Zoology & Nematology Department, Faculty of Agriculture, AL-Azahar Cairo University according to ***Jenkins (1965)***.

2. Weed control rate:

Weed control rates were determined per m^2 where the number was taken using a quarter meter wooden frame after 30 days from the irrigation post application of treatments ***EL-Nakib (1990)***.

3. Estimation of operating cost:

Awady (1978) devised the following equation to determine the cost of operation for the developed flame unit.

C = P/h (1/a + i/2 + t + r) + 1.2 w.s.f. + m/144 .... (1)

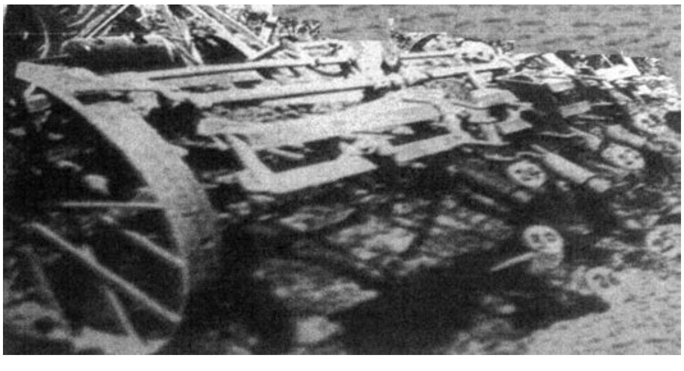
where:

C = Hourly cost
P = Price of machine
h = Yearly working hours
a = Life expectant of the machine
I = Interest rate/year
t = Taxes ratio
r = Repairs and maintenance ratio.
w = Power
s = Specific fuel consumption liter/Hp. hr
f = Fuel price
m = Operator month salary L.E/hr
1.2 = A factor accounting for lubrication
144 = The monthly average working hours

Table 1 A plan for the experiments

Fuel types	Studied factors					
	Changeless factors			Changeable factor		
	Pressure inside tank	High upper blowpipe (m)	Angle upper blowpipe	Width between beams	Forward speed	Sample depth
Kerosene	1.0-1.5	0.13	40	0.25 0.30 0.35	1.9 2.9 4.8	0.05 0.10 0.15

Fig. 2 Rear view of developed flame unit



Results and Dissuctions

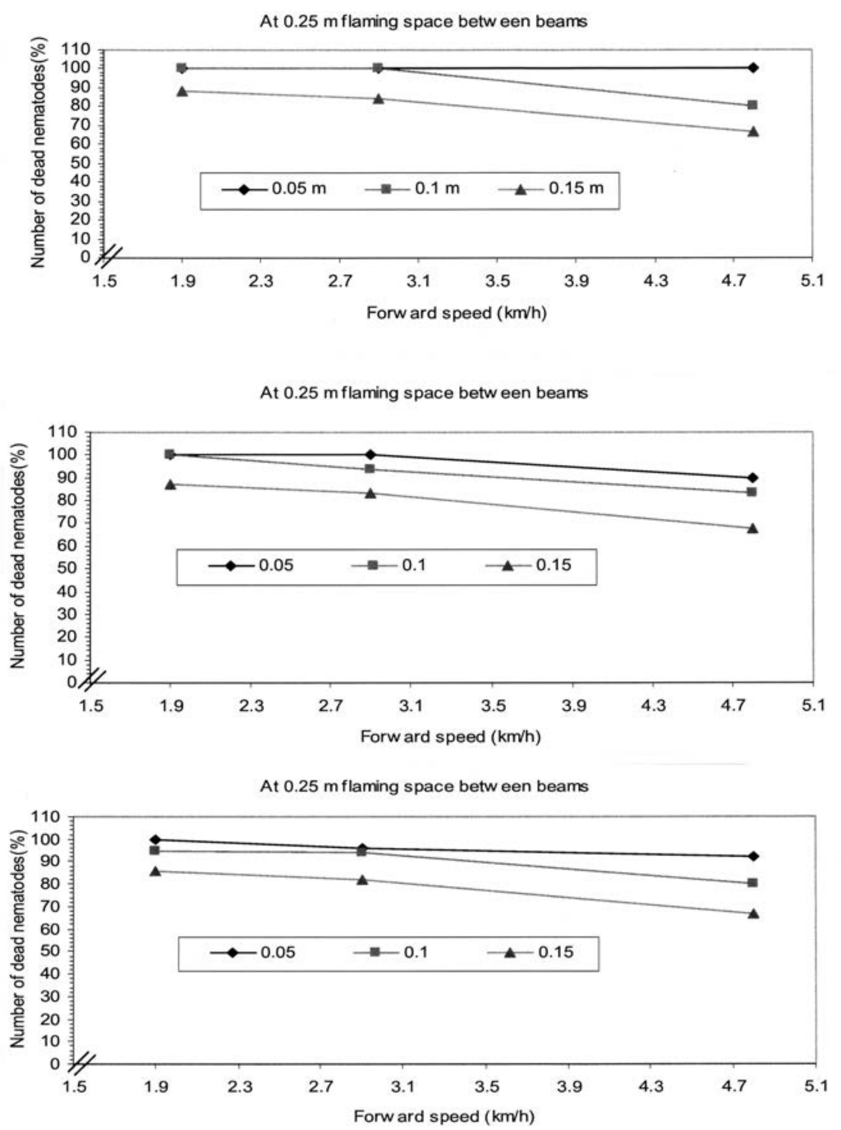
Fig. 3 shows that there is a flow rate in all curves. That meant the existence of an indirect proportion between dead nematodes percentage and forward speed under study. Also, at 0.25 m width between beams, a depth 0.05 m and three levels of forward speed the data gave a horizontal straight line; this meant that all nematodes were dead.

Comparing data in **Table 2** and **Fig. 3**, it was found that there was always a decrease in the dead nematode percentage with increased width between beams, forward speed and depth as compared with control samples. Also, a significant influence was shown for the interaction among all treatments under study on dead nematode percentage. The highest dead nematode percentage (100 %) was achieved at seven treatments as shown in the same mentioned table. The least dead nematodes percentage (67 %) was obtained at a width between beams of 0.35 m, forward speed of 4.8 km/hr and depth of 0.15 m. From the same mentioned data, one can realize that all treatments under study caused decrement in nematodes but this decrement was not fixed. This could be due to the heat loss

Table 2 Nematodes/250 gm of soil at different depths

Tr.	Nematodes at D_1	∝	Nematodes at D_2	∝	Nematodes at D_3	∝	Mean	∝
Con.	260	---	330	----	425	--	339	--
W_1V_1	0	100	0	100	52	88	17	95
W_1V_2	0	100	0	100	69	84	23	93
W_1V_3	0	100	50	80	140	67	63	81
W_2V_1	0	100	0	100	55	87	18	95
W_2V_2	0	100	20	94	71	83	30	91
W_2V_3	25	90	55	83	135	68	71	79
W_3V_1	0	100	15	95	59	86	74	78
W_3V_2	10	96	20	94	75	82	35	90
W_3V_3	20	92	65	80	139	67	74	78
Mean	32	88	56	83	122	71	69	80

Fig. 3 Percent of dead nematodes at different studied factors



of flame through the soil, the poor effect on increasing flame length (L) and scattering of the heat of the flame.

L.S.D for:

D 1% = 3.4 5% = 2.1

WV 1% = 4.3 5% = 3.2

DWV 1% = 7.4 5% = 5.8

$\propto = 129 + 102.2\ W + 17.7\ V + 822.2\ D$

$R^2 = 82.8 \quad R = 92$

Number of Weeds Per M2 of Soil

Fig. 4, in general, showed that the controlled rate decreased with increasing width between beams and forward speed. At the same time, drawn data in **Fig. 4** caused flow curves. This meant that there was an indirect relationship between forward speed and controlled rate for weeds. On the other hand, width between beams of 0.25 m achieved a superior productivity (controlled rate) over the two others. Data collected in **Table 3** showed the existence of a significant influence on percentage of controlled weeds at all treatments under study as compared with control samples. In other words, the interaction among all the same mentioned treatments under study caused a significant impression on controlled weeds percentage. The largest controlled weed percentage (γ) was 95.4 % and was obtained at a width between beams of 0.25 m. and forward speed of 1.9 km/hr.

The smallest controlled weed

Table 3 Percent controlled weeds (γ)

Seric	W	V	Weeds No/1 m^2	γ
1	Control	----	392	----
2	0.25	1.9	18	95.4
3	0.25	2.9	26	93.2
4	0.25	4.8	85	78.3
5	0.30	1.9	113	71.2
6	0.30	2.9	124	68.4
7	0.30	4.6	130	66.8
8	0.35	1.9	138	64.8
9	0.35	2.9	151	61.5
10	0.35	4.8	158	60.0
Mean	---	---	105	65.6

Table 4 Field capacity, cost and fuel consumption at different treatments under study

Treatment	Field capacity feddan/hr	Cost L.E/ feddan	Fuel consumption liter/feddan
W_1V_1	3.10	128.59	186.0
W_1V_2	2.03	84.20	121.8
W_1V_3	1.23	51.02	73.8
W_2V_1	2.81	116.56	168.6
W_2V_2	1.84	76.32	110.4
W_2V_3	1.11	46.04	66.6
W_3V_1	2.56	106.19	153.6
W_3V_2	1.68	89.69	100.8
W_3V_3	1.01	41.89	60.6
Mean	1.93	80.06	115.8

percentage (60 %) was obtained at a width between beams of 0.35 m. and 4.8 km/hr forward speed. One could say that controlled weed percentage decreased with both increasing width between beams and forward speed. This could be as a result of lessening the heat concentration with increasing the treatments under study and vice versa.

L.S.D for:

D 5% = 3.9 1% = 5.1

WV WV 5% = 7.1 1% = 9.4

$\gamma = 259.5 + 1080\,W + 12.8\,V$

$R^2 = 88.5 \quad R = 94.6$

The cost of the developed flame unit and tractor (Naser 60 hp) was estimated according to **Eqn. 1**:

$c = p/h\,(1/a + i/2 + t + r) + 1.2\,w.s.f. + m/144$ .... (1)

Using data provided, the cost could be calculated as follows:

1. Tractor cost:

c = 20000/1000 (1/10 + 16/200 + 2/100 + 10/100) + 1.2 × 60 × 0.15 × 0.41) + 100/144 = 11.12 L.E/hr.

2. Machine cost:

c = 300/600 (1/10 + 16/200 + 2/100 + 10/100) + (1.2 × 60 × 0.41) + 100/144 = 30.36 L.E/hr.

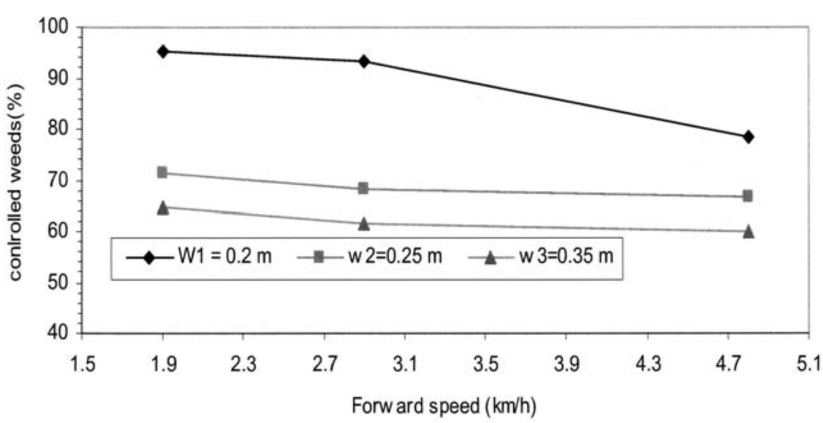
Total cost = 11.12 + 30.36 = 41.48 L.E/hr.

Special Prediction Equation

By using the similitude and dimensional analysis (Murphy 1950) to predict Q (fuel consumption) as a special prediction equation suppose that the following variables are constant.

- s.t. Surface tension of kerosene
- μk Viscosity of kerosene (kinamatic)
- S.W. Specific weight of kerosene
- g Standard gravitation
- d Diameter of outlet opening
- ρk Density of kerosene
- P Pressure inside tank

Fig. 4 Percent controlled weeds at different studied factors



List of pertinent quantities:

Primary values:

Width between beams	w, m	L
Forward speed	V, m/hr.	LT^{-1}
Head of kerosene	H, m	L

Secondary values:

Fuel con-sumption	Q, m^3/hr	L^3/T^{-1}

Determination of groups:

π's = 4 − 2 = 2 groups

Built up the dimensional matrix:

Variables

Dim.	W	V	H	Q
L	(1)	1 0	1	3 2
T		−1 (1)		−1 1
	W	V	H	Q
L	1		1	2
T		1		1
	Reduced matrix		π1	π2

$\pi_1 = H / W,\ \pi_2 = Q / W^2V,$

Check of dimensionless:

$\pi_1 = H / W = L / L = 1$

$\pi_2 = Q / W^2V = L^3T^{-1} / L^2 \times LT^{-1} = 1$

Check of independency:

	W	V	H	Q
π_1	−1 (1)		1 −1	
π_2	−2 0	−1 (1)	−2 2	1 −1
	W	V	H	Q
π_1	(1)		−1	
π_2		(1)	2	−1

.. Rank = 2

∴ groups are independent

∴ the special prediction equation:

$\pi_1 = f\,(\pi_2)^n$ or $Q / W^2V = C\alpha(H / W)^n$

Numerical values:

W = 0.25, 0.30 and 0.35 m.

V = 1900, 2900 and 4800 m/hr.

H = 0.05, 0.10 and 0.15 m.

Determination of the exponent (n):

Table 5 Values of π_1 and π_2

π_1	log π_1	π_2	log π_2
1.5×10^{-3}	−2.81	0.20	−0.69
6.7×10^{-4}	−3.17	0.40	−0.39
2.5×10^{-4}	−3.61	0.60	−0.22
9.9×10^{-4}	−3.01	0.17	−0.77
4.4×10^{-4}	−3.36	0.33	−0.48
1.5×10^{-5}	−4.82	0.50	−0.30
6.6×10^{-4}	−3.18	0.14	−0.85
2.8×10^{-4}	−3.55	0.29	−0.54
1.1×10^{-4}	−3.96	0.43	−0.37

Evaluation of Cα:

Substituting the value of (n) in the special prediction equation yields:

$Q / W^2V = C\alpha\ (H / W)^n$

$n = -0.3$ (see **Fig. 5**)

When the different values of π_1 and π_2 from **Table 5** are inserted into the special equation in turn, numbers of different values of Cα can be obtained as follows:

Cα = 0.0017, 0.00083, 0.00032, 0.0011, 0.00038, 0.000018, 0.00066, 0.0003 and 0.00011 the mean is 0.0006.

Thus the special prediction equation of discharge is as follows:

$Q / W^2V = 0.0006\ (H / W)^{0.3}$

$\therefore Q = 0.0006\ W^2V\ (H\ W^{-1})^{0.3}$

$\therefore Q = 0.0996\ W^2V\ H^{0.3}\ W^{-0.3}$

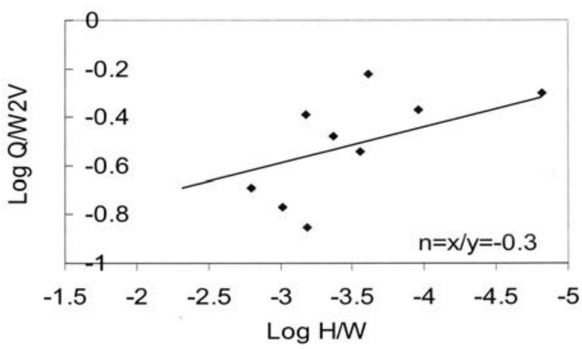
$Q = 0.0006\ W^{1.7}VH^{0.3}$

Conclusion

A simple flame unit fitted on a chisel plow was developed, tested and evaluated. The following conclusions were drawn:

1. Using the flame to control of pests can reduce the chemical applications that increase environmental pollution, especially as an alternative method for methyl bromide used in sterilizing new reclaimed soil that causes cancer and is forbidden by the United Nations.
2. The flaming application is a considerably better method than mechanical, which diffuses the weeds rhizomes in the soil.
3. This treatment could be applied to control soil pests once every year.
4. Planting legume crops after treatment, or green manure, could compensate the loss of organic matter, decrement of micro-organisms and other elements.
5. The results showed that all nematodes died and the highest effect on weeds was at 0.25 m space between beams, 0.05 m flame depth and the first level of forward speed (1.54 km/h).

Fig. 5 Determination of the exponent (n)



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■■

Agitator Unit in Auger Metering Device for Fertilizer Applicator

by
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Abstract

This investigation was carried out to study the engineering parameters of auger volume, cross sectional area of the orifice gate, fertilizer density and feeding shaft speed that effect the discharge rate, g/min, and the percent volumetric efficiency of the fertilizer applicator. The results indicated that the highest value of discharge rate was 2,660 g/min obtained at the orifice gate with a cross section area of 48 cm^2, auger volume of 50.66 cm^3 and feeding shaft rotational speed of 11.6 m/s for a bulk density of 0.685 g/cm^3. The lowest value was 190 g/min at the sequence condition of 2.7 m/s, auger volume of 24.27 cm^3 and gate area of 16 cm^2 for super phosphate. Increasing the gate area from 16 to 48 cm^2 increased the volumetric efficiency from 64.8 % to 78.9 % and from 39.4 % to 51.1 % for bulk density of 0.685 and 0.995 g/cm^3, respectively.

Introduction

The physical properties of fertilizer are the major factors that effect on the volumetric flow rate of the metering mechanism. Klenin *et al.* (1985) indicated that the change in size of mineral fertilizers, hygroscopicity, disperse-ability, density, tendency to scatter and cake and other properties influenced the functioning of designed machines. They added that the mineral size had a significant effect on machine operation and, as granule size increased above 5 mm, the effect became progressively weaker and lead to poor spreading. Hygroscopicity of fertilizers, in most cases, determined their properties that directly influence the machines qualitative indices operation. The ability of fertilizers to disperse was governed by moisture content, which depended on their hygroscopicity. Scattering of fertilizer granules was defined as the ability to form an arch over orifices. This factor was characterized by the pressure that must be applied to destroy the compact arch of fertilizer granules of 60 mm height formed over the orifice. Hofstee and Huisman (1990) discussed particle motion in both spinning disc and reciprocating spout fertilizer distributors. Five important properties that affect particle motion were reviewed, namely, particle size distribution, coefficient of friction, coefficient of restitution, aerodynamic resistance and particle strength. The latter was indirectly related to particle motion. Methods for determining the properties and the results of different tests were discussed and relevant data for the 5 properties reviewed were presented.

Hofstee (1994) used a new technique for measuring the velocity and direction of fertilizer particles discharged by a fertilizer distributor. The technique was based on the frequency shift of an ultrasonic beam. The instantaneous amplitude and frequency of the received doppler signals were computed by digital signal processing. The velocity and the direction of each detected particle were calculated from the instantaneous frequency and the particle diameter was estimated from the instantaneous amplitude. The technique was used to quantify the influence of physical properties of fertilizer on the motion of fertilizer particles in the distributor device. A first series of experiments showed that this technique could measure the velocity and direction of fertilizer particles. The estimation of the particle diameter was more difficult because of the non uniform frequency response that used the ultrasonic transducers in the frequency band. Csizmazia and Andersson (2000) indicated the majority of fertilizer spreading was solid state world-wide. Consequently, a technical development was to be performed to improve coefficient of variation of the fertilizer distribution and increase the working width of the spreaders. The evenness of the spread pattern depended largely on the physical properties of the fertilizer. The influence of the physical properties on the particle motion through the air was very important. Dutzi (2002) discussed the measurement of the main physical characteristics of different types of dry fertilizers. These included the grain size distribution, the actual and bulk densities, grain strength, flow characteristics and friction on the spreading disc. The use of these data in assessing the various spreading characteristics of different fertilizer material was described, together with the practical measurement of actual performance in the test.

Until now, many problems face the auger-type of fertilizer distributor metering devices. Therefore, the objectives of this paper were to study the engineering parameters that control the proposed fertilizing applicator performance and to test the performance of the proposed fertilizer applicator.

Materials and Methods

The fertilizer distributor unit consisted of fertilizer hoppers, metering device, transmission system and agitator and fertilizer tubes. Fertilizer particles are usually different in shape from one type to another (powered–granular–crystallize), along with physicochemical properties, (bulk density–moisture content), mechanical properties, (friction angle–repose angle) and also in the application rate. Therefore, there were three hoppers, which have a cross section at the top 360 × 360 mm, and trapezoidal at the bottom. In order to facilitate the flow of materials to slide down along the hopper walls, the latter must be inclined under a relevantly large angle (600); larger than the friction angle of the fertilizers against the hopper walls. Controlled gates were fixed on the hopper's sides near the bottom. Each hopper had a capacity of 35 kg of fertilizer (**Fig. 1**).

As shown in **Fig. 1**, the metering device consisted of three augers with different pitch lengths and screw flight diameters of 5.3, 6.0 and 5.8 cm. The screw shaft diameter for all was 3.9 cm with a pitch length of 2.4, 2.4 and 3.5 cm, respectively. The volumetric capacity of the three different augers were 24.27, 39.19, 50.66 cm^3 and were located, one by one, on the feeding shaft hoppers as shown in **Fig. 1**. The theoretical volumetric capacity of the auger by was defined by Srivastava (1993) as:

$$Q_{th} = \frac{\pi}{4}\left[(d_{sf})^2 - (d_{ss})^2\right] I_p\, N \quad .... (1)$$

where

Q_{th} = the theoretical volumetric capacity, cm^3/min

d_{sf} = screw flight diameter, cm

d_{ss} = screw shaft diameter, cm

I_p = pitch length, cm

N = screw rotational speed, rpm

The transmission system had two functions for driving the metric device from a land wheel, and for changing the auger shaft rotating speed to obtain different application fertilizer rates, kg/Fed. A vertical agitator was used to prevent bridging in the hopper with the powdered materials. It was located inside the right hopper only, **Fig. 2**. There were three slide control gates, which were fixed on the hopper sides to control the amount of flow from the hopper to auger (**Fig. 3**). The total cross section of the orifice gates was 150 × 80 mm. A rubber tube of 25 mm diameter was mounted to the outlet of each tank. The ends of these tubes were collected in a small

Fig. 1 Fertilizing hoppers

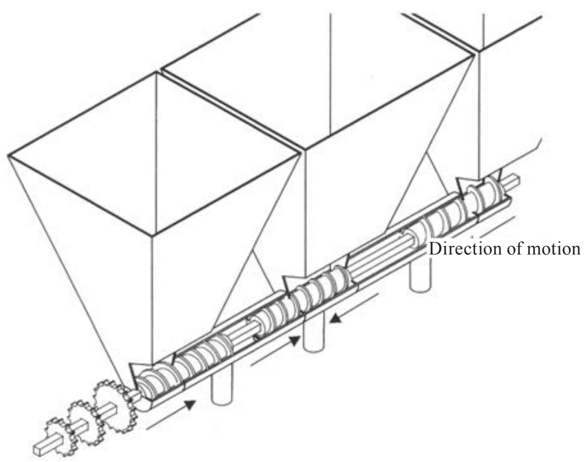


Fig. 2 The vertical agitator

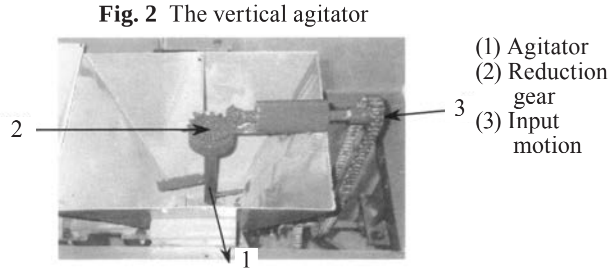
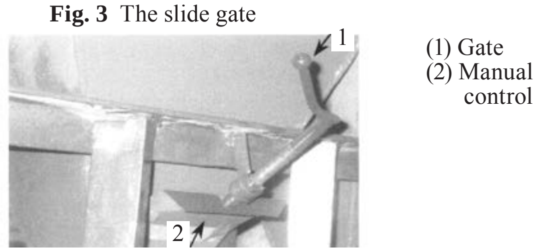


Fig. 3 The slide gate



collector, which poured out from the point carrying fertilizer to the soil surface.

A strip-plot design was used to evaluate the effect of the experimental factors on the proposed design. The parameters were twelve rotating speeds of the auger shaft (N), three levels of augers volume (V), two kinds of fertilizers (Ft) and three-orifice gate areas (Ga) were replicated three times. The resulting number of plots was 216 in each replication.

Measurements were made to evaluate the fertilizer flow and two parameters were determined; namely, the discharge rate, g/min (D) and the volumetric efficiency percentage (ηv). Bulk density was measured by filling a known container volume with the different fertilizers. Then, the mass of different fertilizers was determined and the bulk density was calculated from the principle equation. A digital measuring device was used to measure the friction angle that was designed by (Matouk *et al*., 2003) and the angle of repose was measured using an angle of repose apparatus designed by (Matouk *et al*., 2006).

The discharge rate (g/min) was measured three times in the laboratory by operating the auger shaft for one minute for each treatment under different treatments. Generally, the discharge rate was expressed in terms of mass per unit time, g/min, as follows:

$Q_a = D / \rho$ ....(2)

In reality, the actual capacity of an auger was consider less than the theoretical capacity. Then the volumetric efficiency, ηv, was defined as:

$\eta_v = Q_a / Q_{th} \times 100$ ....(3)

where

Q_a = actual volume capacity, cm^3/min

D = discharge rate, g/min

ρ = bulk density of the material, g/cm^3

η_{th} = volumetric efficiency, %

All data collected for all parameters of different treatments were statistically analyzed. The strip plot design (Gomezz and Arture 1984) was adopted in these studies for statistical analysis of the data by the SAS computer program. In order to ascertain whether the observed treatment effects were real and discernible from chance effects, the "Null Hypothesis" was tested by "F" test at the 5 % level of probability as well as LSD at 1 % of probability (in case of highly significant differences) according to Sendecor and Cockran (1981).

Results and Discussion

The Discharge Rate of the Metering Device

Fig. 4 shows the effect of the auger shaft speed on the discharge rate of different fertilizers at different auger volumes. In general, a linear relationship between the discharge rate, g/min, and auger shaft speed, m/s, was obtained. It was obvious that increasing the auger shaft speed increased the discharge rate for all levels of auger volumes. A gate area of 16 cm^2 and the amount of discharge rate of fertilizer, g/min, were 480, 870 and 1,060 g/min, obtained at 24.27, 39.19 and 50.66 cm^3 auger volume, respectively, and at 7.21 m/s auger shaft speed for super phosphate. The results for urea were 680,

Fig. 4 The discharge rates of fertilizing metric device at the gate area of 16 cm^2

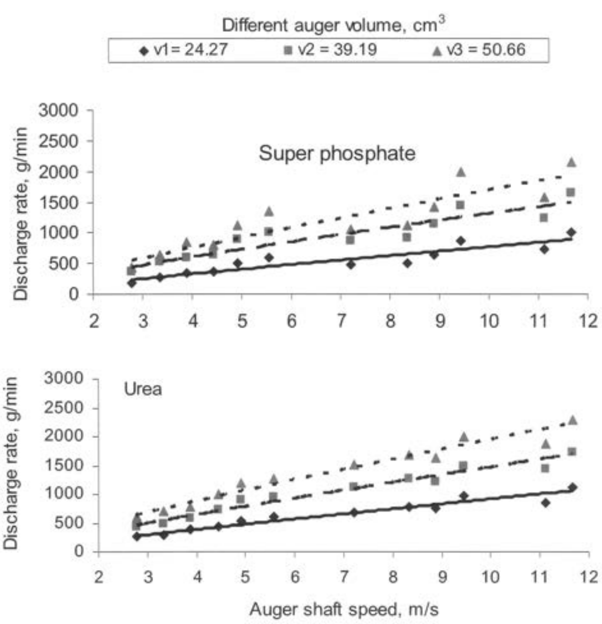
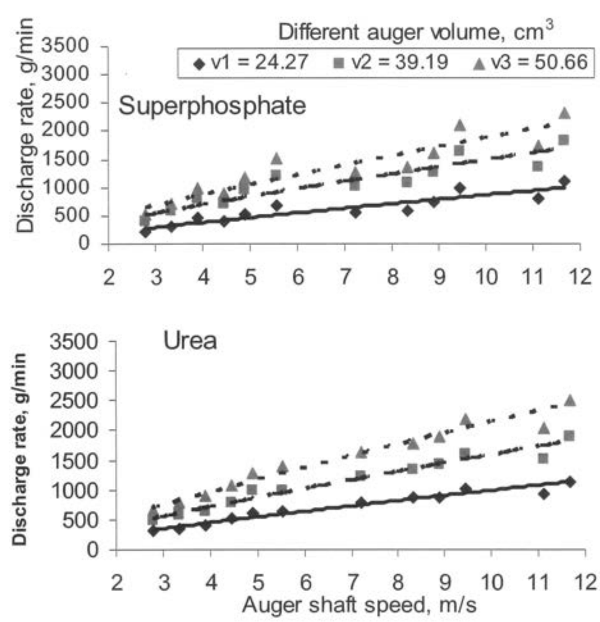


Fig. 5 The discharge rates of fertilizing metric device at the gate area of 32 cm^2



1,130 and 1,520 g/min under the previous conditions.

At a gate area of 32 cm², the change in discharge rate when the auger shaft speed was increased from 2.77 to 11.66 m/s was 19.82 %, 22.55 % and 22.32 % at 24.27, 39.19 and 50.66 cm³ auger volume, respectively, for super phosphate. These were 28.7 %, 26.84 % and 26.98 % for urea at the previous conditions (**Fig. 5**).

As shown in **Fig. 6**, at a gate area of 48 cm², the discharge rates of fertilizer were 650, 1,115, and 1,420 g/min obtained at 24.27, 39.19 and 50.66 cm³ auger volume, respectively and at 7.21 m/s auger shaft speed for super phosphate. The results for urea were 1,390 and 1,830 g/min under the previous conditions.

The general trend of this relationship was that, with increasing auger shaft speed, auger volume and cross sectional area, the discharge rate increased. A simple power regression analysis was applied to relate the change in discharge rate with the change in auger shaft speed for all treatments. The obtained regression equation was:

$D = aN^b$ ....(4)

Table 1 Values of constants (a and b) of **Eqn. 4**

Fertilizer type	Auger volume, cm³	Gate area, 16 cm²			Gate area, 32cm²			Gate area, 48cm²		
		a	b	R2	a	b	R2	a	b	R2
Phosphate	V_1 = 24.24	92.524	0.92	0.87	112.52	0.89	0.86	141.68	0.88	0.845
	V_2 = 39.19	184.54	0.85	0.88	220.26	0.83	0.86	275.8	0.78	0.835
	V_3 = 50.66	223.89	0.88	0.84	270.7	0.84	0.87	331.95	0.80	0.832
Urea	V_1 = 24.24	106.98	0.94	0.96	138.8	0.86	0.97	150.26	0.87	0.982
	V_2 = 39.19	185.17	0.90	0.97	214.18	0.87	0.97	237.06	0.87	0.985
	V_3 = 50.66	261.88	0.87	0.97	287.23	0.87	0.97	316.19	0.87	0.989

where:

D = the discharge rate, g/min;

N = the auger shaft speed, m/s;

a and b = coefficient constants

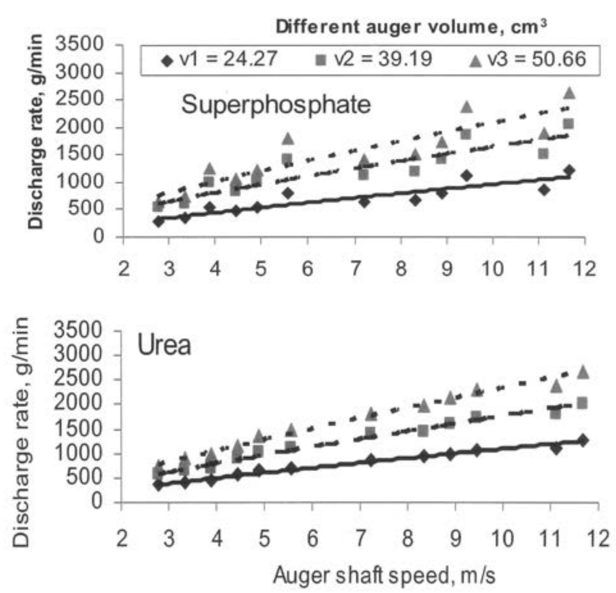
The regression constants (a and b) for all obtained regression equations are tabulated in **Table 1**.

The SAS analysis indicated a highly significant difference for the treatments of auger shaft speed to the discharge rate. The values of gate area, auger volume and fertilizer bulk density recorded a highly significant efficiency. Also, the total interaction between different treatments showed a significant effect with R^2 = 0.993 and CV = 5.4 %, except the interactions of $V \times F_t \times G_a$ and $N \times V \times F_t \times G_a$.

The general multiple regressions for the interaction between the operating parameters against the discharge rate are indicated the following **Eqn**:

$D = 0.583\ (VN\rho) \quad R^2 = 0.93$

Fig. 6 The discharge rates of fertilizing metric device at the gate area of 48 cm²



The Metering Device Efficiency

The effects of auger shaft speed, auger volume, and orifice gate area for different fertilizer types on the volumetric efficiency are illustrated in **Figs. 7** and **8**. The general trend of this relationship was that the volumetric efficiency increased directly with increasing auger speed up to 5.5 m/s for most treatments. Beyond this value, the volumetric efficiency decreased. This trend might be attributed to the fact that after this point the centrifugal force restricted the flow of fertilizers.

The results indicated that the highest value of the volumetric efficiency was 86 % obtained when the orifice gate was adjusted to a cross section area of 48 cm², auger volume capacity of 50.66 cm³ and auger shaft speed of 4.44 and 4.99 m/s for spherical shaped particles (urea). The lowest value was 28 % for a gate area of 16 cm², auger volume of 24.27 cm³ and speed of 8.33 m/s, for powdered shaped particles (super phosphate).

Fig. 7 gives a graphical presentation of results for gate areas of 16, 32 and 48 cm² and auger volumes of 24.27, 39.19 and 50.66 cm³ using super phosphate. The volumetric efficiencies of fertilizer, ηv %, were 49 %, 67 % and 67%, at 16, 32 and 48 cm² gate area, respectively, and at 5.55 m/s auger shaft speed for auger volume of 24.27 cm^3. The same results were 51 %, 62 % and 72 % for auger volume of 39.19 cm^3 and 54 %, 60 % and 71 % for auger volume of 50.66 cm^3 under the same conditions of gate area; 16, 32 and 48 cm^2, respectively, and auger shaft speed of 5.55 m/s for super phosphate.

For urea, at auger shaft speed of 4.99 m/s the volumetric efficiencies were 71%, 80% and 86%, obtained at 16, 32 and 48 cm^2 gate areas, respectively, for auger volume of 24.27 cm^3. The same results were 75 %, 81 % and 86 % for auger volume of 39.19 cm^3 and were 77 %, 82 % and 86 % for auger volume of 50.66 cm^3 under the same conditions of gate areas 16, 32 and 48 cm^2, respectively, and auger shaft speed of 4.99 m/s, as shown in **Fig. 8**.

The effect of auger shaft speed on volumetric efficiency at different fertilizer type of bulk density was analyzed using the regression analysis. The results showed that, the relationship between the studied variables could be described as follows:

$$\eta_v = -k N^2 + I N + n \quad (5)$$

where

η_v = volumetric efficiency, (%);

N = auger shaft speed, (m/s);

k, I and n = coefficient constants.

The values of the constants k, I and n are presented in **Table 2**. The statistical analysis showed no significance difference between the levels of 2.77 and 9.44 m/s, 3.33 and 2.77 m/s, 3.88 and 4.44 m/s, 5.55 and 4.99 m/s and 11.66, 8.33 and 8.88 m/s on the volumetric efficiency.

Conclusions

The Conclusions of this Paper are Summarized as Follow:

1. The highest value of discharge rate was 2,660 g/min, which was obtained when the orifice gate was adjusted at a cross sectional area of 48 cm^2, auger volume of 50.66 cm^3 and rotational speed of feeding shaft of 11.6 m/s for urea. For super phosphate the lowest value was 190 g/min at the same condition of 2.7 m/s, auger volume of 24.27 cm^3 and gate area of 16 cm^2.
2. Increasing the gate area from 16 to 48 cm^2, increased the volumetric efficiency from 64.8 % to 78.9 % at a bulk density of 0.685 g/cm^3. It increased from 68.5 % to 80.7 % and from 39.4 % to 51.1 %, with a bulk density of 0.995 g/cm^3.

Fig. 7 Effect of auger shaft speed on volumetric efficiency using super phosphate

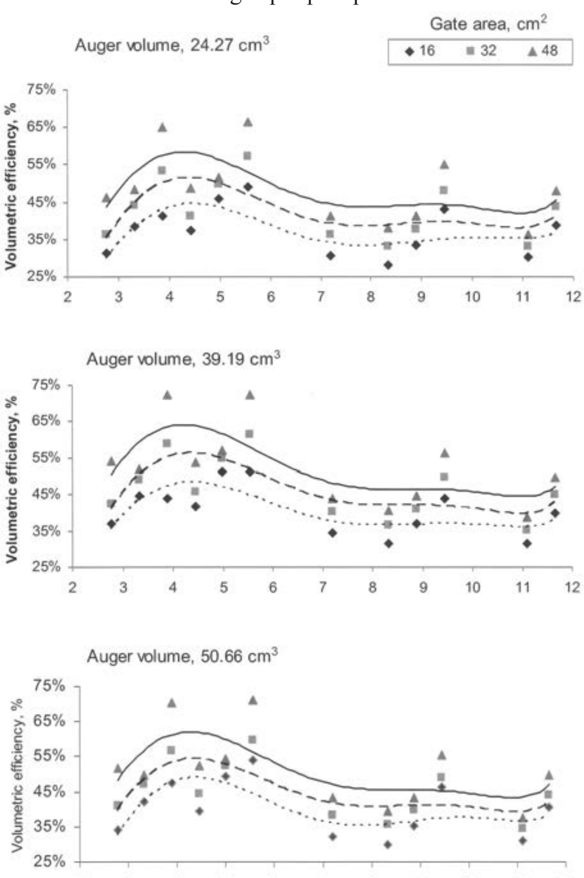


Fig. 8 Effect of auger shaft speed on volumetric efficiency for Urea

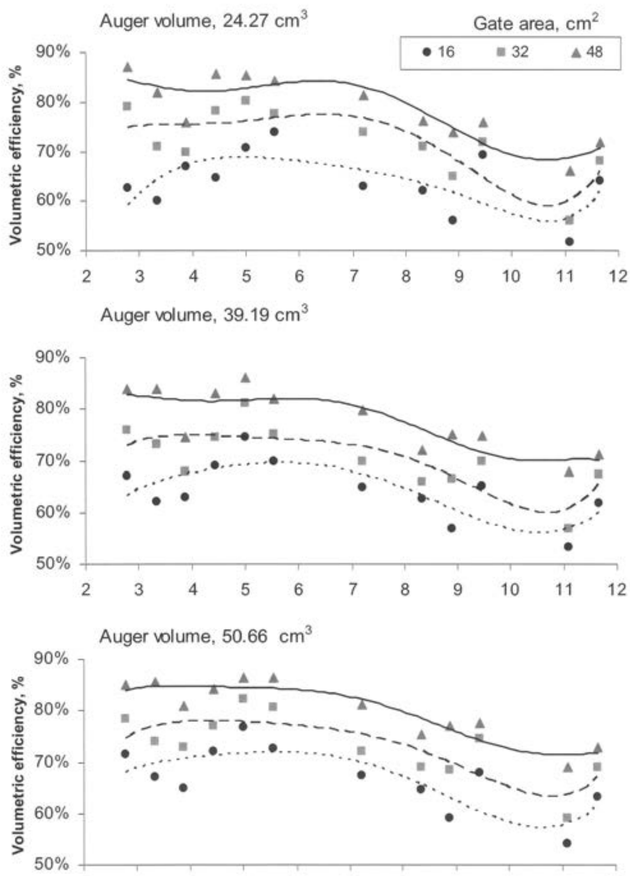


Table 2 Values of constants (k, l and n) of **Eqn. 5**

Fertilizer name	Bulk density, g/cm^3	k	l	n	R^2
Urea	0.685	0.0019	0.0131	0.7341	0.611
Phosphate	0.995	0.0009	0.0012	0.4941	0.2032

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ABSTRACTS

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

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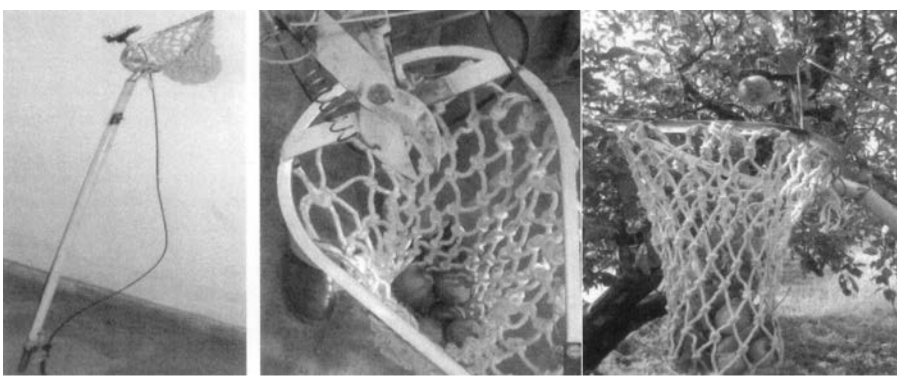
Design and Development of Clutch Lever Operated Fruit Picker of Adjustable Height: **Jagvir Dixit,** Dept. of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana, Punjab, INDIA; Email: jagvirdixit@yahoo.com, **G. M. Mir**, Assistant Professor, SKUAST-K, Division of Agricultural Engineering, Shalimar-191121 (J & K) INDIA.

A fruit picker of adjustable height was developed to overcome human drudgery by traditional fruit picking practice. Although the device is simple in design, yet very effective. The device consisted of Clutch lever, a clutch wire, an extension mechanism, a cutting mechanism and head with a flexible basket for fruit collection. It can pick fruits up to a height of 5-6 meter and weighs only 1,480 gm including handle. The test results of the device showed that fruit picking capacity of 55-65 and 45-55 kg/h were attained in case of apple and pear, respectively. Negligible damage was observed with the developed picker. The cost of the device of about Rs. 600 makes is affordable to even a marginal orchardist.

Fig. 2 Overall view of the developed fruit picker



Off Season Cultivation and Techno-Economic Evaluation of Okra Grown under Greenhouse

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Abstract

An experiment was conducted during winter 2007-08 and 2008-09 in a semi-cylindrical greenhouse 4 m × 25 m each for cultivation of okra at Bhubaneswar in coastal Orissa, India. The greenhouse was effective in raising the temperature inside the greenhouse during cold nights, thereby, creating a better microclimate for production of higher yield and quality fruits than open field cultivation. The growth and yield of okra was better under greenhouse than open field cultivation. The yield of okra per sq m inside the greenhouse was 2.42 times more than open field conditions. 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 worth of investment made on the greenhouse for cultivation of okra was Rs. 11,056 as compared to Rs. 884 when grown in the open field. The benefit cost ratio for the greenhouse was 1.19 and 1.06 for open field cultivation. The internal rate of return for the greenhouse was 14 and 11 percent for open field cultivation. The pay back period for okra under the greenhouse was 14. Techno-economically cultivation of okra in winter under greenhouse would be acceptable by the farmers of Orissa.

Introduction

Presently, in India 7.49 million ha are cultivated with vegetable with an annual production of 116.03 million tonnes. It is estimated that, by 2020 the vegetable demand of the country could be around 135 million tonnes. To achieve this target, attention must be focused on the vertical expansion, strengthened with the boon of the technology instead of horizontal expansion just by increasing the crop area (Rai and Pandey, 2008). The working group on horticulture constituted by the Planning Commission of India had recommended deployment of hi-tech horticulture and precision farming for achieving vertical growth in horticulture.

Hi-tech interventions in horticultural crops proposed by the National Committee on Plasticulture Applications in Horticulture, Government of India is greenhouse technology (Samuel and Singh, 2004). Greenhouse crops are one of the most profitable cash crops and, being of short duration, the benefits from the cultivation can be derived within a period of 3-4 months (Mishra and Paul, 2003). The cost of a greenhouse varies from Rs. 100/- to Rs. 1,000/- per square metre or even more depending on the kind of environmental control and automation required (Annonymous, 2005). It must also be recognized that the degree of sophistication and level of investment per square metre of greenhouse must be appropriate to the application if the technology is to be economically justifiable. As most of the parts of India have warm climate, the first expectation is that opportunities for greenhouse technology would be quite limited. However, there are a number of circumstances in which there are opportunities for greenhouse technology to make a significant contribution to the sustainability of agriculture and to the economic well being of farmers.

In most of the agro-climatic zones in India the commercial use of the greenhouse is production of quality planting materials and production of off-season vegetables. In many temperate climatic areas of the world, vegetable farmers find that they can substantially increase income if they can start planting in a greenhouse earlier than they can plant outdoors, enabling them to bring produce to the market early when prices are higher. Such opportunities seem to exist in India also.

In coastal Orissa, the mean air temperature varies from 25.00 to 37.17 ºC in summer, 24.53 to 32.72 ºC in rainy and 14.88 to 28.33 ºC in winter seasons. During cold season there is a high demand for vegetables like okra (Abelmoschus esculentus Moench.), which is a crop of summer and rainy season (Annonymous, 2002). This is generally sown from the end of February to the end of March as a summer crop and May to August as rainy season crop. Optimum temperature requirement for normal growth and yield of okra crop is 25 to 28 ºC, which is higher than that that prevails in winter season (Bose *et al*., 1996). Hence, there is a need to increase the temperature for safe growing of this vegetable in winter season, as it is grown under open field in Orissa. As the greenhouse allows faster temperature increase during sunny days and slower temperature decrease in night hours, it is considered to be the most suitable structure for off-season cultivation of okra. But, higher operating cost of a high-tech controlled greenhouse will be a constraint for popularization of this technique in a state like Orissa where 75 to 85 percent of farmers are small and marginal. With this in the background, the present study was undertaken of the suitability of a low-tech naturally ventilated greenhouse for off-season cultivation of okra, environmental parameters and techno-economics in coastal Orissa, India.

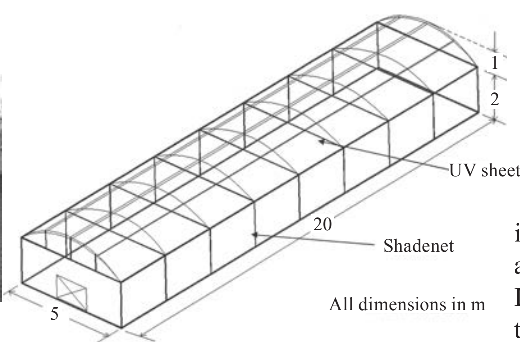
Materials and Methods

The experiment was conducted inside and outside a greenhouse erected by Precision Farming Development Centre, Orissa University of Agriculture and Technology, Bhubaneswar, Orissa, India during two consecutive years 2007-08 and 2008-09. The place is situated at 20º 15″ N latitude and 85º 52″ E longitude with an elevation of 25.9 m above the mean sea level and nearly 64 km west of the Bay of Bengal. The experimental greenhouse was a naturally ventilated single span greenhouse made of a G.I. structure covering an area of 100 sq m oriented in the East-West direction (**Fig. 1**). The greenhouse was covered with ultra violet (UV) stabilized low density polyethylene (LDPE) film of 200-micron thickness. The height of the greenhouse from the floor to the roof top was 3 meters at the centre. The four sides of the greenhouse were covered with nylon made shadenet with 50 % opening (**Fig. 2**). The soil of the area was clay loam and acidic in nature having pH of 6.1. Okra seed (variety MHOK-417) was planted with a spacing of 45 cm × 30 cm. The cultural practices of the crop were followed as per the recommendations by the Indian Council of Agricultural Research, New Delhi (Thamburaj and Singh, 2003).

Observations on growth character and yield of okra crop were recorded inside the greenhouse and under open field cultivation. To study the effect of greenhouse on capsicum crop, observations on environmental parameters like air temperature, relative humidity and soil temperature both at 7.30 A.M. and at 1.30 P.M. were recorded inside and outside the greenhouse.

Fig. 1 Outside view of the experimental greenhouse

Fig. 2 Isometric view of the greenhouse



Techno-Economic Analysis

An attempt was made to determine the economics of the cultivation of okra under greenhouse. Four economic indicators; net present value (NPV), benefit-cost ratio (BCR), internal rate of return (IRR) and pay back period (PBP) were used. Several research workers in the past have used these indicators for different agricultural systems (Kothari *et al*., 2001; Seveda *et al*., 2004; and Jain *et al*., 2004). Values of all these indicators were computed as:

$$NPV = \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} \quad \text{...............} (1)$$

$$BCR = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}} \quad \text{...................} (2)$$

B_t and C_t are the benefit and cost in each year; t= 1, 2, 3,…. N years and i is the discount rate in percent. IRR is the discount rate that makes the NPV to the incremental net benefit stream or incremental cash flow equal to zero. It is computed by **Eqn. 3**:

$$\sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} = 0 \quad \text{......................} (3)$$

Pay back period is the length of time between cumulative net cash outflow recovered in the form of yearly net cash inflow.

Assumptions made for economic consideration were:

1. The life of greenhouse structure is 20 years.
2. The life of greenhouse cover is 5 years.
3. Discount rate is assumed to be 8 percent as compared to bank lending rate of interest (Kothari *et al*., 2001 and Sevede *et al*., 2004).

Results and Discussion

Growth Parameters and Yield

Overall growth of okra in terms of days to germination and height of the plants inside the greenhouse was better as compared to open fields. Early seed germination occurred in the protected greenhouse conditions with nearly 18 percent less time required as compared to outside conditions. Plant height at harvest inside the greenhouse was 22 percent higher than open field conditions. Considering the quality aspects, the length and diameter of fruit grown inside greenhouse was 95 and 84 percent higher under the greenhouse than in the open field, respectively. The number of fruits per plant was 59 percent more under the greenhouse than outside. The fruit yield per sq m inside the greenhouse was 2.42 times more than the open field conditions. The okra sown during off-season under greenhouse produced 142 percent higher fruit yield than the normal sowing date in the open field (0.49 kg/m^2) (**Table 1**).

Table 1 Growth and yield of okra under greenhouse and open field cultivation

	Greenhouse	Open field
Days to germination	4.75	5.83
Plant height, cm	73.97	60.5
Fruit diameter, cm	5.62	3.05
Fruit length, cm	10.73	5.5
Fruit weight, gm	9.65	6.6
No. of fruits per plant	15.92	9.96
Fruit yield/plant, gm	166.42	73.0
Fruit yield/m^2, kg	1.26	0.48

Environmental Parameters

The variation of environmental parameters like air temperature, relative humidity and soil temperature at 7.30 A.M. are presented in **Figs. 3** to **5**, respectively. At 7.30 A.M. the air temperature inside the Greenhouse was about 1 to 3 ºC higher than the open condition during the cropping season (**Fig. 3**). The soil temperature inside the greenhouse was 1 to 4 ºC at 7.30 AM than the outside during the crop growing period. The variation in relative humidity in open condition ranged from 30.7 to 53.8 % and inside greenhouse from 46.2 to 59.1 % (**Fig. 5**).

The variation of environmental parameters like air temperature, relative humidity and soil temperature at 1.30 P.M. are presented in **Fig. 6** to **8**, respectively. Similarly, at 1.30 PM the air temperature inside the greenhouse was 0 to 7 ºC more than outside during all the weeks (**Fig. 6**). The soil temperature inside the greenhouse was 1 to 7 ºC higher than outside during the observation period (**Fig. 7**). The variation in relative humidity in open condition ranged from 35.2 to 57.6 % and inside greenhouse it varied from 42.5 to 63.1 % (**Fig. 8**).

The day and night temperature was higher in greenhouse in comparison to open condition. The cladding material exerted a blanket effect at the top resulting in less fluctuations of day and night temperature than open conditions. In open conditions the higher variation in day and night temperature resulted in lower yield. It was also effective in raising the temperature during cold night periods inside the greenhouse thereby creating a better microclimate for production of higher yield and quality fruits (Koning, 1988). The shadenet on four sides of the greenhouse provided natural

Fig. 3 Weekly average air temperature at 7.30 A.M.

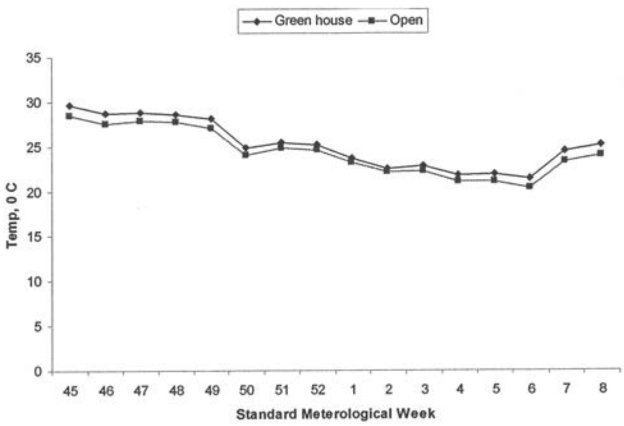
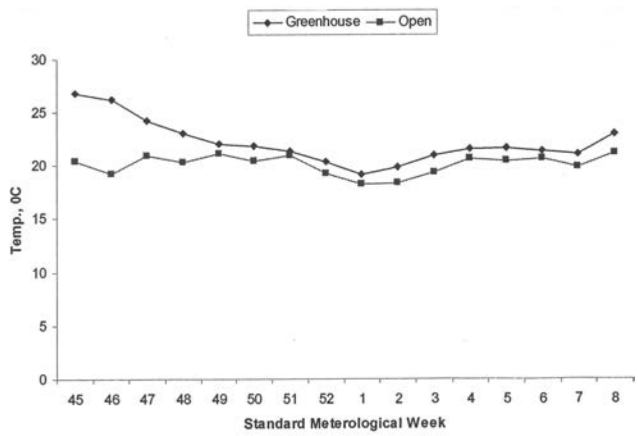


Fig. 4 Weekly average soil temperature at 7.30 A.M.



ventilation resulting in reduction of relative humidity inside the greenhouse. The yield was in agreement with findings in okra and capsicum (Nimji *et al*., 1990).

Economic Feasibility

The yield of okra was 359 kg and 144 kg under greenhouse and open field cultivation, respectively. The cost of the greenhouse was computed to be Rs. 40,000/-. The cost of the UV sheet and shadenet for the greenhouse was Rs. 2,160/- and Rs. 2,520/-, respectively, which would be changed in every fifth year. The cost of cultivation of okra was Rs. 1,310/- and Rs. 1,250/- under greenhouse and open field cultivation, respectively. Total return from greenhouse and open field cultivation was Rs. 7,180/- and Rs. 1,440/-, respectively per year. During the study the following results related to economic viability were obtained for cultivation of okra under different growing conditions.

The NPV for okra crop was Rs. 11,056/- under greenhouse and was Rs. 884/- outside the greenhouse. Based on NPV it was concluded that the construction of a greenhouse for cultivation of okra crop was economical and there was substantial increase in the income of the farmer by growing this crop inside the structure (**Table 2**).

The benefit cost ratio was 1.19 inside the greenhouse and 1.06 in open field cultivation. The IRR was another important factor frequently used by economists for evaluation of the performance of different projects. It was computed as that interest rate at which the BCR was just 1.0. The IRR was 14 percent when grown inside greenhouse as compared to 11 percent when grown in open field (**Table 2**). As these IRR were more than the bank lending interest rate (8 %), the project was economically viable. The payback period was 14 years when grown inside greenhouse, which was less than the life span of the greenhouse (20 years). Thus farmers could pay

Table 2 Economic indicators for okra under greenhouse and open field cultivation

Economic indicator	Greenhouse	Open field
N_{pw}, Rs	11,056	884
BCR	1.19	1.06
IRR, %	13	11
PBP, years	14	-

Fig. 5 Weekly average relative humidity at 7.30 A.M.

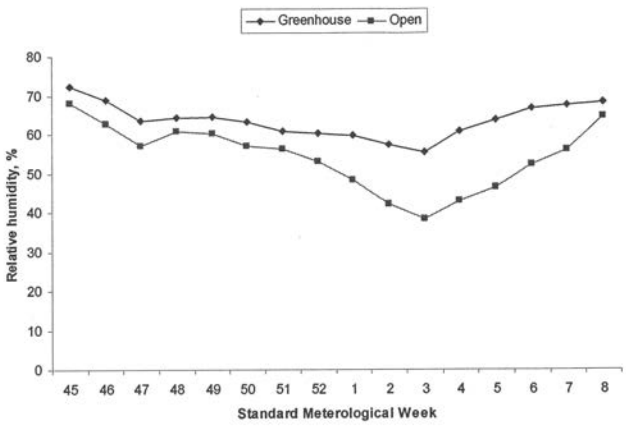


Fig. 6 Weekly average air temperature at 1.30 P.M.

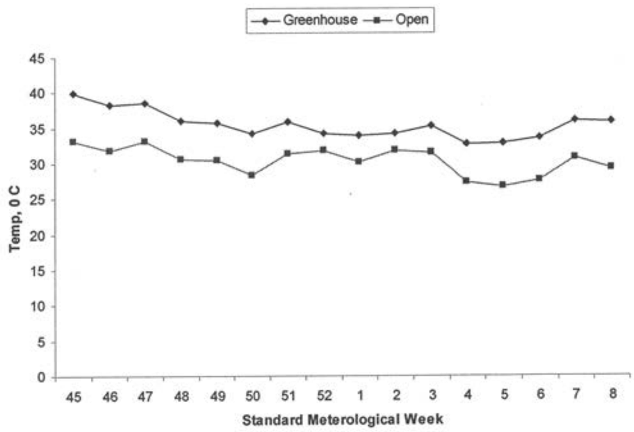


Fig. 7 Weekly average soil temperature at 1.30 P.M

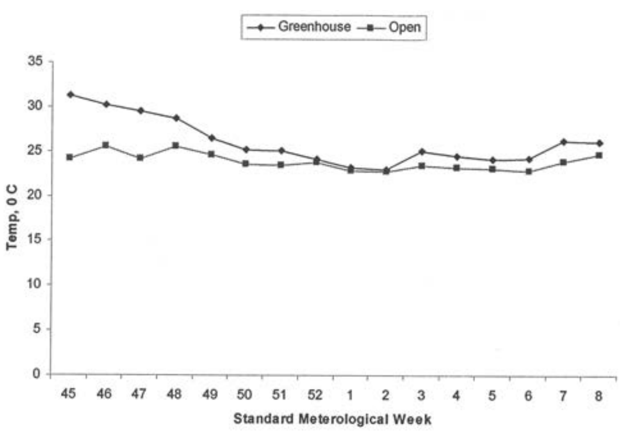
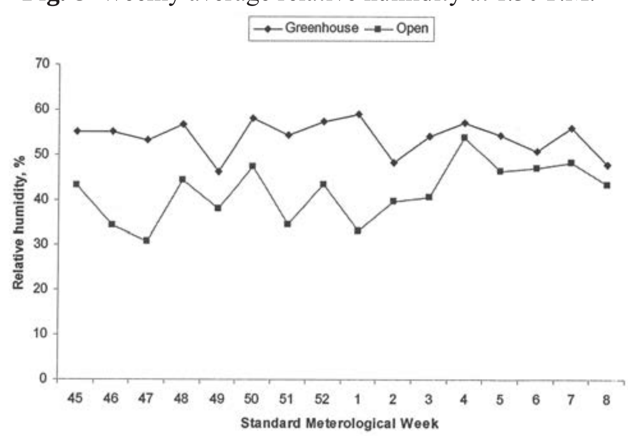


Fig. 8 Weekly average relative humidity at 1.30 P.M.



back their investment in 14 years.

Conclusion

The greenhouse was effective in raising the temperature during cold night periods 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 okra was better under the greenhouse than open field cultivation. The yield of okra per sq m inside the greenhouse was 2.42 times more over open field conditions. NPV of investment made on the greenhouse was Rs. 11,056/-, as compared to only Rs. 884/- for open conditions for okra. The benefit cost ratio for okra in the greenhouse was 1.19. The internal rate of return in greenhouse was 14 percent. The payback period for the greenhouse was 14 years. From the above study, the economic indicators suggested that cultivation of okra under protected conditions was economical under the coastal climate of Orissa as an off-season crop.

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Post-Harvest Technology of Betel Leaf (*Piper Betle* L.): Effect of Curing on Quality and Physiological Parameters

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Abstract

Paan is a local name of betel leaf in many Asian countries like India, Pakistan, Bangladesh where it is an important cash crop from the time immemorial. Over 20 million people in India alone are associated with its production, processing, handling, transportation, marketing and consumption. This leaf contributes about Rs. 6,000-7,000 million every year to the Indian National Income. The leaf is consumed by a large portion of population in many Asian countries on a regular basis in its natural, fresh and raw condition along with lime, areca nut, catechu, aniseed, coriander seed, cardamom and clove mainly for the purpose of attaining digestive, stimulating and mouth freshening effects. In view of the continuously rising demand for fresh betel leaves and its highly perishable nature, a need was felt for improving its post-harvest quality. Consequently, in some villages in India, the farmers started curing betel leaves traditionally with the help of wood charcoal smoke in a closed chamber and thereby improving taste, mouth feel, shelf life and other qualities but the physiological changes associated with such attempt have not yet been well studied. Therefore, the present investigation was carried out during 2008 and 2009 at IIT, Kharagpur and Menkapur village of West Bengal, India. The objective of this study was to find the physiological parameters and quantify the changes associated with improvement in organoleptic qualities of betel leaves due to curing treatments. The physiological parameters studied in the experiments included: pH, Electrical Conductivity (EC), nutrients (N, P, K), protein, chlorophyll, fiber and carbohydrate contents while the organoleptic qualities of the cured leaves were examined through leaf-colour, taste and mouth feel. The results of the study indicated that green colour of the leaves gradually faded with curing treatments due to bleaching effect besides loss of chlorophyll and ultimately turned out to be white or yellowish white. The results also indicate that pH values gradually increased with number of curing from 5.16 to 6.58 but the fiber content of the leaves remained close to 2.20 % only. On the other hand, values of EC, chlorophyll, carbohydrate and protein contents gradually decreased with number of curings from 0.36 Siemens/m to 0.20 Siemens/m, from 0.59 mg/g to 0.07 mg/g, from 6.84 % to 2.73 % and from 23.04 % to 16.30 %, respectively. A similar trend was also observed with N, P and K contents, which decreased from 3.69 % to 2.61 %, from 0.56 % to 0.46 % and from 1.09 % to 0.94 %, respectively. The cumulative effect of such changes, particularly that of leaf-colour, pH and chlorophyll was clearly perceptible in the organoleptic qualities of the cured leaves which gradually improved with increase in number of curings. This helped the farmers in obtaining a higher selling price of the cured leaves in the market.

Introduction

Paan is a local name of betel leaf in many Asian countries like Bangladesh, India, Nepal, Pakistan, etc (Khoshoo, 1981; Samanta, 1994; Jana, 1996; and Sharma *et al*., 1996). It has been an important cash crop in these countries from the time immemorial. The leaf also has a great socio-economic and demographic importance which would be evident from the fact that over 20 million people in India alone are associated with its production, processing, handling, transportation, marketing and consumption (Guha and Jain, 1997). That apart, trading of this leaf contributes about Rs. 6,000- 7,000 million every year to Indian national income whereas the Indian Railways earn about Rs. 100 million every year by transporting betel leaves from West Bengal to different parts of the country (Guha, 2006). Further, leaves worth about Rs. 30-40 million are exported to different countries of the world like Bahrain, Canada, Great Britain, Hong Kong, Italy, Kuwait, Nepal, Pakistan and Saudi Arab (Jana, 1996 and Singh *et al*., 1990). These leaves are consumed by a large portion of population in these countries on a regular basis in its natural, fresh and raw condition along with lime, catechu, areca nut, aniseed, coriander seed, cardamom and clove according to personal choice and taste of the consumers mainly for the purpose of attaining digestive, stimulating and mouth freshening effects. In view of the continuously rising demand for fresh betel leaves and its highly perishable nature, a need was felt for improving its post-harvest quality. Consequently, in some villages in India, farmers started curing betel leaves traditionally with the help of wood charcoal smoke in a closed chamber and thereby improving colour, taste, mouth feel, shelf life and other qualities. The process was probably invented at Benaras (U. P.), India and therefore, such leaves were renamed as Benarasi *Paan* which is a much preferred item over the fresh leaves in many parts of India particularly, Bihar, Delhi, M. P., Chhattisgarh, Rajasthan, U. K. and U. P. However, the physiological changes associated with such attempt of improving post-harvest qualities have not yet been well studied. Therefore, the present investigation was undertaken during 2008 and 2009 at IIT, Kharagpur and Menkapur village of West Bengal province of India. The objective of this study was to find the physiological parameters and quantify their changes associated with improvement in organoleptic qualities of betel leaves due to curing treatments.

Materials and Methods

Experiments were carried out during 2008 and repeated during 2009 at Menkapur village of Dantan subdivision and also at IIT, Kharagpur. Both the places are situated in West Midnapur District of West Bengal province of India. The Menkapur village is located at *21º57'0"N* latitude and *87º16'12"E* longitude, with an altitude of 25 m above the mean sea level while Kharagpur is located at *22º19'0"N* latitude and *87º19'0"E* longitude, with an altitude of 48 m above the mean sea level. The curing treatments were given to the fresh green betel leaves inside the curing unit. The units were constructed with locally available cheap materials like straw, bamboo, cane, clay, bricks, cow dung, etc. A single unit covered about 150 m^2 area housing two adjoining curing chambers and adequate working space. The twin curing chambers were constructed with bricks and clay (mud) and were alternately used. The approximate size of each curing chamber was 3 m × 2.5 m × 2 m (L × W × H) and each chamber accommodated 51 baskets arranged in 3 shelves made of bamboo chips and each basket contained about 1,500 de-petiolated betel leaves. After loading one curing chamber with baskets full of Bangla variety of local betel leaves, 2.5 kg wood charcoal was ignited inside the chamber in closed condition for producing smoke. After about 1 hr and 30 min, the chamber was opened and baskets were taken out and kept in open environment for cooling as well as sorting out the spoiled leaves for 2 days. Thereafter, the baskets were moved into the chamber again and the same process was repeated up to five times which took about 15 days

Table 1 Effect of curing treatments on physiological parameters of betel leaf

Treatments* (No of Curing)	Chlorophyll Contents, mg/g	Greenness (SPAD meter reading)	Carbohydrate Content, %	Fiber content, %	Nitrogen content, %	Phosphorus content, %	Potassium content, %	Protein content, %	pH	Electrical conductivity (Siemens/meter)
T_0	0.59	39.63	6.84	2.20	3.69	0.56	1.09	23.08	5.16	0.36
T_1	0.51	35.23	4.43	2.20	3.34	0.55	1.05	20.89	5.66	0.28
T_2	0.46	31.58	3.42	2.18	3.06	0.53	1.02	19.14	5.88	0.26
T_3	0.41	28.40	3.30	2.18	2.85	0.50	1.00	17.83	6.03	0.23
T_4	0.29	19.50	3.07	2.23	2.75	0.48	0.98	17.17	6.22	0.22
T_5	0.07	4.53	2.73	2.20	2.61	0.46	0.94	16.30	6.58	0.20
C. D. (P = 0.05)	0.0007	0.211	0.10	NS	0.02	0.0007	0.007	0.13	0.006	0.0007

*T_0 = Control (Fresh leaves), T_1, T_2, T_3, T_4, T_5...represents 1, 2, 3, 4 & 5 curings; NS=Non significant

in total. The experiment was conducted with six treatments (**Table 1**) and six replications in a randomized complete block design. An average of two years' data were used for the statistical analysis.

The parameters studied in the experiments included leaf-colour, pH, electrical conductivity (EC), N, P, K, protein, chlorophyll, fiber and carbohydrate content of the leaves, which were determined after each treatment of curing along with the control (untreated fresh leaves). The leaf colour was directly measured with a SPAD meter whereas pH and EC were measured from leaf extracts obtained with distilled water (1:10) by the respective meters. Further, four dilutions of HCl were prepared (**Table 2**) and the relevant observations were recorded for pH and EC for explaining the relationship of pH and EC of the leaf extracts. Chlorophyll, phosphorus and carbohydrate were measured by spectrophotometric methods whereas nitrogen and potassium were measured by micro-kjeldahl and flame-photometric methods, respectively, following the procedure described by Yoshida *et al.* (1976). After determination of nitrogen content, the values were multiplied with 6.25 for calculating the protein content of the leaves. The fiber content of betel leaves, however, was determined with the method reported by Bidwell and Bopst (1922). For taking observation on the above parameters, a standard sampling technique was followed and the samples were prepared in a uniform manner. After giving treatments to the basketful of leaves, six baskets were randomly selected from the lot of 51 baskets and then thirty leaves were collected randomly from each of the selected baskets separately and mixed thoroughly before using these as samples. The working samples were then prepared from these leaves by taking whole leaf, cut pieces (1 cm^2), dry powder or water extract (1:10) as per the required procedure.

For determination of organoleptic qualities, all types of treated leaves (1 to 5 curings) along with the untreated fresh green ones (control) were put to organoleptic examination by the habitual betel leaf consumers. Morsels or quids of betel leaves were prepared with standard non-tobacco based pre-mixed paan-masala (spicy ingredients) collected from a betel leaf morsel vendor of the local market. The said "masala" consisted of areca nut chips, catechu, lime, cardamom, aniseeds, clove and chaman bahar (branded spicy condiment mixture). The quids were then given to 20 habitual consumers who were instructed to categorise the quids according to colour, taste and mouth feel into five different groups (**Table 3**). An average of two year's data were then rounded to a whole number and expressed as percentage of the total count (i.e. 20) under each group (**Table 3**). The organoleptic examination was conducted on five different dates and on each date only one type of cured leaves (leaves with any one treatment) was tasted along with the control.

Results and Discussion

The results of the present study clearly indicate that the fiber content of the leaves did not change significantly with increase in number of treatments of curing and remained close to 2.2 percent before as well as after the treatments of curing (**Table 1**). As such, fiber content may not have any bearing on the organoleptic improvements associated with curing of the leaves. On the contrary, all the other physiological parameters showed a significantly decreasing trend except pH which revealed an increasing trend (**Table 1**). The pH of fresh betel leaf juice increased from 5.16 to 6.58 after five treatments of curing indicating reduction in acidity of the leave obviously due to breakdown of organic acids present in the leaves. Dastane *et al.* (1958) also found an increase in pH due to curing but did not explain the reasons behind such change. However, gradual decrease in electrical conductivity of leaf juice with increase in number of curing treatments also gives a clear cut indication of destruction of organic acids present in the leaves (**Table 1**). Similar inverse relationship of pH and electrical conductivity of acid (HCl) in all dilutions (**Table 2**) also clearly indicates the same reasoning. Further, it is a well

Table 2 Relationship of EC and pH at different concentration of HCl

Concentration of hydro-chloric acid, %, v/v	Electrical conductivity (Siemens/ meter)	pH
0.1	120.50	1.15
0.01	26.80	1.93
0.001	0.18	2.86
0.0001	0.11	3.79

Table 3 Effect of curing treatments on organoleptic qualities of betel leaf

Treatments* (No of Curing)	Organoleptic scores (%)				
	Very bad	bad	normal	good	very good
T_0	15	15	50	15	5
T_1	10	10	45	30	5
T_2	5	15	35	35	10
T_3	5	5	30	40	20
T_4	5	5	20	50	20
T_5	0	5	10	60	25

*T_0 = Control (Fresh leaves), T_1, T_2, T_3, T_4, T_5...represents 1, 2, 3, 4 & 5 curings

know fact that presence or absence of acids in any food article have an important bearing on organoleptic quality parameters particularly, the taste of the article. Therefore, improvement in organoleptic qualities of cured betel leaves (**Table 3**) can be explained by decrease in acidity in the leaves due to curing treatments.

The greenness of the leaves gradually decreased with each treatment of curing and at the end of fifth curing the relevant SPAD meter reading came down from 39.63 to 4.53 (**Table 1**). This change was clearly visible with naked eyes because the fresh green leaves turned white or yellowish white indicating almost complete loss of green colour. The loss of green colour may be explained by the fact that chlorophyll content of the leaves was almost completely destroyed due to unfavourable conditions prevailing inside the curing chambers like absence of light (dark condition), high temperature (36-40 ºC), and presence of smoke during the curing process. This can be further substantiated by the measured values of chlorophyll that came down from 0.59 mg/g in fresh leaves to 0.07 mg/g in the finally cured leaves (**Table 1**). Similar results though have been reported by Mann *et al.* (1916), Dastane *et al.* (1958), Ramanna *et al.* (1988), Ramalakshmi *et al.* (2002) and Rasyaguru *et al.* (2007) but the actual biochemical mechanism of rapid de-chlorophyllation and de-greening effects have not yet been fully explained by any research worker. However, the consequences of destruction of chlorophyll were clearly detectable in the present study by a significant decrease in carbohydrate content of the fresh leaves which came down from 6.84 percent to 2.73 percent after five treatments of curing. Such decrease in carbohydrate content might have also been contributed by lack of light required for photosynthesis in the dark curing chamber besides continuous respiration of the living cells present in the leaves oxidizing the reserve carbohydrates for deriving energy and thereby releasing CO_2 and water. Similar depletion of carbohydrates in the cured leaves was also noted by Dastane *et al.* (1958) who observed also that there was decrease in non-reducing sugars vis-á-vis increase in reducing sugars due to curing treatments. Thus, change in sugar levels might have also contributed to better organoleptic qualities of the cured leaves, particularly by altering the sweetness of the final product. So far as the major nutrients are concerned, there was only nominal and fractional (up to 0.1 %) decrease in P and K contents of the leaves due to curing. This can possibly be explained by loss of cell sap from the leaves particularly through the cut petioles during curing mainly due to high turgor pressure of the freshly harvested leaves besides the heavy load exerted by the weight of the bundles of betel leaves causing one kind of squeezing effect. This, however, does not fully explain the substantial loss of nitrogen (up to 1 %) from the leaves due to curing. There is no widely published literature to explain such loss so far as betel leaf is concerned. However, it may be explained by similar loss of nitrogen during curing of tobacco leaf (*Nicotiana tabacum*) when leaf protein undergoes enzymatic hydrolysis producing amino acids (Frankenburg, 1946), which again undergoes oxidative de-amination producing free ammonia besides carbon dioxide and carbonyl compounds (Hodge, 1967). The escape of free ammonia gas containing nitrogen might have contributed to reduction in N-content of the cured leaves. Consequently, there was substantial and proportional reduction (up to 6 %) in protein content of the leaves (**Table 1**). Thus, nutritional value of the leaves was also decreased significantly. However, such reduction in protein content does not reduce the consumptive value/food value of the leaves because the leaves are not consumed as a bulk food item for obtaining proteinous nutrition; rather, the leaves are consumed in small quantities of 1-5 leaves weighing about 3-15 g/day or less as a mouth freshening, digestive and stimulating agent.

Data pertaining to organoleptic examination of betel leaf is presented in **Table 3**, which clearly indicate that there was substantial improvement in taste, mouth feel and leaf-colour of the betel leaves due to curing. This was evident from the fact that the organoleptic scores of cured leaves under very bad group decreased from 15 % to 00 % (zero percent) with increase in number of curing treatments. Whereas the scores under good and very good groups increased from 15 % to 60 % and 5 % to 25 %, respectively. Further, though the maximum organoleptic scores of fresh betel leaves were recorded under normal group but the maximum scores of the finally cured leaves were recorded under good group. However, very bad scores (ranging from 5 to 10 %) were also recorded under different curing treatments (**Table 3**). This can be explained by the fact that due to the tobacco habit (addiction), some tasters did not like the non-tobacco based quids used for organoleptic examination of the cured leaves. Further, change in colour of the leaves from green to white or yellowish white made the product more consumer-appealing. Such improvement in organoleptic qualities of the leaves helped the farmers in obtaining higher selling price of the cured leaves in the market.

Conclusions

The following conclusions can be drawn from the present study:

1. There was substantial improvement in organoleptic qualities of betel leaves due to curing com-

pared to the fresh ones.
2. All the physiological parameters, except fiber content, were associated in different degrees with improvement in organoleptic qualities of betel leaves due to curing.
3. The pH values showed an increasing trend while all other physiological parameters revealed a decreasing trend during curing except fiber content, which remained unchanged.

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Moisture Content Effect on Sewage Sludge for Land Farming Application

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Abstract

The presence of moisture content in treated sewage sludge for land farming application and its characteristics are a growing factor that determines the quality of the performance in terms of nitrogen, phosphorus and potassium concentration. This paper provides information about general awareness on the moisture content effect on treated sewage sludge in terms of different particle size and its effect on nitrogen, phosphorus and potassium concentration. Sewage sludge particles of 1.40 mm, 2.00 mm and 2.80 mm mesh were used for the investigation. Results obtained in terms of the effect of moisture content on the characteristics and composition of NPK concentration on sewage sludge was investigated. The results obtained for one day exposure on moisture content concentration of 1.40 mm mesh is within the range of 58-88 % reduction for drying period of 3 min at temperature of 60-100 ºC. The NPK concentration for 1.40 mm mesh, as obtained from research, shows N_{pw} (1.4) = 0.0084-0.0362 mol%, P_{pw} (1.4) = 0.007-0.021 mol%, K_{pw} (1.4) = 0.007-0.023 mol%. The results obtained for moisture content concentration of 2.00 mm and 2.80 mm was within the range of 54.50 to 83.00 % and 56.50-80.00 % reduction for dying period of 3 min at temperature of 60-100 ºC. The NPK concentration is within the range of N_{pw} (3.0) = 0.12-0.032 mol %, P_{pw} (2.0) = 0.008-0.023 mol %, K_{pw} (2.0) = 0.010-0.026 mol %. The analysis after treatment was within the same international standard for land farming application. Microbial analysis of the samples showed that fecal coliform of microorganisms were present and the fecal coliform was isolated and identified using standard methods. The results obtained from this investigation showed that the sewage sludge after treatment could be in land farming application.

Introduction

Land application of sewage involves taking advantage of the fertilizer content by soil conditioning properties of sewage sludge. This is done by spreading the treated sewage on the soil surface to provide the necessary soil nutrients like nitrogen, arsenic, cadmium, copper, selenium and organic matter. The problem of domestic waste in environmental management has become an issue of serious concern in all over the world particularly in Nigeria. The increasing population and urbanization in Nigeria has resulted in an intensive environmental awareness that aims at meeting the needs of the present without compromising the ability of future generations in gaining from the common environment (Leton, 1998; 1999; EGASPIN 2002; Gerand, 1998; Mark and Hammar, 1993; Metacalf and Eddy, 1991 and USEPA 1987). The sewage generated from homes contain much suspended solid particles, organic materials, inorganic salts, ammonia, sulphides, sodium, nitrogen, oxygen and others ingredients which are useful to the soil nutrient when treated. Others contain some hazardous organic acids, inorganic materials, offensive odor and some pathogenic organisms. This leads to better methods of collecting the sewage from the environment and depositing in a good place to be well treated for reuse to avoid environmental degradation (Reed and Crites, 1984).

The moisture content of a material is usually expressed as a percentage of the mass of dry material. It varies when the material is exposed to air at a given temperature and humidity. Water is gained or lost until an equal state between the moisture content of the materials and the atmosphere is attained at a particular temperature. This state is called equilibrium moisture content and varies with both the material and the temperature. Results from various groups on the effect of moisture content characteristics revealed that the percentage of the moisture content on sewage sludge influence the functional parameters and when applied on any agricultural land the aim may not be achieved (Braz, 2005; Arcadio and Gregorian, 1999; Abbort and Clamen, 1973; Henderson, 1961). This unacceptable characteristic of sewage sludge after treatment due to high percentage of moisture content can affect the soil nutrient, surface water, ground water pollution, contamination of soil and crops with high toxic substances. The percentage of the moisture content helps in reducing the toxicity of substances present in the sewage sludge to the minimum allowable limit as recommended by International Standard for land farming application (Ong & Bowers, 1990; Finstein *et al.,* 1987; Seginer, 2006; and Abbort, 2007). Wang and Singh, 1978; Demir *et al*., 2004; and Inci and Dursin, 2002). The aim of this work is to investigate the characteristics of sewage sludge suitability in terms of composition of nitrogen, phosphorus and potassium (NPK) for land farming application as well as to determine the possible factors responsible for poor quality and outline the possible solution on how to improve the quality. Another aim is to assess the effect of moisture content on the characteristics of sewage sludge as well as composition of nitrogen, phosphorus and potassium after treatment to achieve the best operating temperature range in which international standard quality can be obtained.

Materials and Methods

Collection of Samples

The sewage sludge samples were collected from IDS Onne, at the outskirts of Port Harcourt. The samples were collected by using a plastic bucket and then transported to the Department of Chemical/Petrochemical laboratory in Rivers State University of Science and Technology, Port Harcourt for analysis as well as setting up the experiment. This was done by tying a rope on the handle of the bucket, covering our nose with nose mask, allowing the bucket to go deep down the sewage in the septic tanks and dump sites, allowed the bucket to be filled with the raw sewage, take the rope out with the filled bucket gradually after which it was covered properly making sure that our hands are well protected with gloves.

Residential Areas

In many residential areas most sewage was mainly from the kitchen, toilets, bathrooms and other minor waste from the residents. The sludge from these areas was mixed. The collection of these waste were from soakaways and septic tanks. The sewage sludge used for this study was collected from a soakaway, septic tanks and sewage reservoirs in IDS yard at the outskirts of Port Harcourt. The samples were collected in big bowls and the sewage sludge mesh was left for about 3 days to settle. The other stages of the treatments continued after this period.

The sludge mesh was separated into units of 1.40 mm, 2.00 mm and 2.80 mm in diameter. The sludge mesh was weighed at a constant weight of 0.2 kg for each of the samples through out the experiments.

The sludge was dried to temperatures of 60, 70 80, 90 and 100 ºC per each sample, after final drying, within the time range of 5, 4, 3, 2 and 1 minute.

Exposure to Sunlight

The dewatered sample was exposed to the atmospheric air for drying or removal of some moisture content by evaporation. This stayed for about 1 to 3 days before the next stage, which is the final drying. The sample stayed from 8.00 am to 5.00 pm when the sun sets each day and was packed. It was spread the following day and same was done till the third day.

Note that the exposition of the solid sludge to sunlight serves two major purposes. The first was the removal of water from the sludge. The second purpose was to destroy any harmful micro-organism because of the ultra violet (uv) rays received from the sun by the sludge, thereby, making the final product harmless when applied to farm lands.

Pre-Treatment

This was the process that prepares sludge to a condition that it can be further treated in conventional processes for use. That is, the removal of floating debris and grit from the sewage sludge. This was carried out as the samples were brought from the site, they were placed in bigger containers (bowl) and all the floating debris were removed with a filter, leaving the remaining the sewage sludge for further processing.

Screening

This was the removal of large materials like rags and plastics from the sludge. As the samples were collected from the site, all these big materials were removed from the top of the sewage sludge with a coarse screen of about 6 mm. Some of these large materials were floating.

Dewatering

This was the removal of water content from the sewage sludge. The sewage sludge was allowed to stay for some time to settle in the bowl. The volume of water on top of the sludge was removed by decantation. The remaining sludge sample was put in a sack, tied and placed on two sticks arranged on a big bowl or basin to collect the run-off or drain off water to avoid an environmental nuisance.

This was left for a day and the solid sludge was collected for the next treatment.

Mechanical Drying Method (Rotary Method)

This was the final stage of the sludge treatment. After exposing the sludge to the surroundings for drying by evaporation, the sludge sample was then weighed and introduced into the rotary dryer compartment. The machine was switched on and heat introduced into the dryer compartment with the sample. As the temperature increased, the moisture in the sample was given off. This was timed at different intervals of from 1 min to 5 min and the temperature was read at this different times.

Equilibrium Moisture Content

The moisture content of a material is usually expressed as a percentage of the mass of dry material. It varies when the material is exposed to air at a given temperature and humidity, water is gained or lost until an equal state between the moisture content of the materials and the atmosphere is attained at a particular temperature. This state is called equilibrium moisture content. This varies with both the material and the temperature.

For example, a non-porous insoluble solid such as sand has an effective equilibrium moisture content of zero, while the equilibrium moisture content of an organic material such as sewage sludge is quite high. The equilibrium vapor pressure above the sludge is determined not only by the temperature but also by the water content of sludge, by the way in which water is bound in the sludge and by the pressure of constituents soluble in water under a given vapor pressure of water in the surrounding air. It is possible therefore to plot the equilibrium vapor pressure against moisture content.

Moisture Content on Drying Method

The drying method was used to measure the weight reduction in the laboratory by the precise determination of evaporation of moisture content. Determination of the difference in sample weight before and after drying gave exact information on the moisture content. Approximately 0.2 kg of sludge was weighed in a dry bowl for the determination of the moisture content. The sighed sludge from the atmosphere was introduced into the rotary dryer with a process described in this paper. The temperature is controlled and read at different intervals (60, 70, 80, 90 and 100 ºC). The federal institute of industrial research, Oshodi, reported that the amount of moisture content present on the traditional products fibres, stored food and others is 15.5 % for safe storage without risk of spoilage. They also submitted an amount of moisture content of less than 12 % preferably 8-10 %. The standards organization of Nigeria (SON) recommends 12 % of moisture and storage stability. This should, also, apply sludge.

The Total Moisture Content is Calculated with the Following Formula

% of moisture content = 100 − (Sample wt in kg after pre − drying / Sample wt in kg before pre − drying) × (100 − moisture content after fainal drying)

This explains the sequential stage by stage approach of how the entire project work was carried out. Dry sludge was the product obtained when domestic sewage sludge is dewatered and treated by drying. It was in a sack of solid sludge. From the sack it was removed and exposed to the atmospheric air for drying by evaporation, and packed dried by the rotary method. These methodologies are carefully explained one after the other below.

Determination of Npk in the Final Sewage Sludge (Cake) Product

The major components of the final dried sludge cake product were nitrogen, phosphorus and potassium. The process of determination of these three components is identified below.

Determination of Phosphorus

Material and Equipment Used

The material and equipment used to determine phosphorus were funnels, 1 ml pipette, mechanical bottle shaker, 4 ml pipette, B & L spectronic —20 spetro-photometer, test tube with stoppers, 10 ml graduated cylinder, 50 ml volumetric flasks, filter papers, standard phosphorus, 10 ml graduated pipette, Reagent A (solution of ammonium molybodate- $(NH_4)_6MO_7O_{24}$. $4H_2O$, solution of potassium antimony titrate—$KSbOC_4H_4O_6$, diluted H_2SO_4), and Reagent B (ascorbic acid dissolved in reagent A).

Procedure for Determining Phosphorus

A sample of 2.00 g of the final treated sewage sludge cake was weighed into a test tube and 20 ml of the extracting solution was added. The test tube was shaken for about 1 minute and the contents were filtered with whatmann filter paper until the filtrate was clear. 10 ml aliquot of the cake extract was pipetted into a 50 ml volumetric flask and 10 ml of distilled water was added. 4 ml of reagent B was added and made up to a 50 ml volume with distilled water. The contents were allowed to stand for 15 minutes for the colour to develop 1, 2, 3, 4, 6, 8, 10 ml of phosphorus were diluted to 40 ml to obtain 0.1, 0.2, 0.3, 0.4, 0.6, 0.8, and 1.0 ppm of phosphorus standard. 1.0 ml of the extracting solution containing unpolluted sludge filtrate was added to each of the standard. 4 ml of reagent B was also added. The colour was allowed to develop for 15 minutes and the absorbance measured on a spectrophotometer at 660 um. This served as the blank experiment (control) for the sludge sample A graph of absorbance against concentration. This was plotted to give the standard curve used in reading the values of phosphorus present.

Determination of Potassium

Material and Equipment Used

The material and equipment used to determine potassium were a graduated 10 ml pipette, natural gas, flame photometer with suitable filters for potassium, 50 ml volumetric flasks, regulating valves for air and gas, air, ammonium acetate solution containing the sludge cake.

Procedure for Determining Potassium

The concentration of 0, 2, 5, 7 and 10 ppm standards of potassium were prepared by pipetting 0, 2, 5, 7, and 10 m of 100 ppm stock solution of the element into 50 ml volumetric flasks each and diluting the solutions to 50 ml with ammonium acetate solution. 10 ml of ammonium acetate extract prepared during the determination of exchangeable and magnesium was diluted to 50 ml with ammonium acetate solution. Potassium filter was inserted in the instrument. The flame photometer was calibrated by setting the meter needle to zero and then aspirating distilled water to give 20 ppm, the meter needle was set to 100 % emission and 20 ppm standard was aspirated.

After calibration, the test of the standards (2, 5, 7, 10) were aspirated and their emission readings recorded. A calibration curve was plotted of emission readings against concentration of standard. The ammonium acetate extract was aspirated in the flame photometer. The concentration of potassium (K) in sample was determined from the meter reading and the calibration curve.

Determination of Nitrogen

Material and Equipment Used

The material and equipment used to determine nitrogen were burette 50 ml, 50 ml Erlenmeyer flask, semimicro Kjeldahl digestion apparatus, 100 ml erlenmer flasks, Kjeldahl flasks 50ml, Conc. H_2SO_4, K_2SO_4, —plus –catalyst mixture (K_2SO_4, $CuSO_4.5H_2O$ and Se), NaOH (in), mixed boric acid—indicator solution, steam distillation apparatus, measuring cylinder 5ml and a measuring cylinder 50 ml.

Procedure for Determining Nitrogen

The sample of the final sludge was prepared and passed through a 1.4 mm mesh then weighed in a 50 ml kjeldahl flask. 2 ml of distilled water was added and the flask was swirled and then allowed to stand for about 30 minutes. The catalyst, 3 ml of Conc. H_2SO_4 and K_2SO_4 were added.

The flask was then transferred to the digestion stand and low heat was applied. Evaporation of the water occurred and then the heat was increased. When the digest was cleared, the mixture was boiled for about 5 hr with the flask being rotated at intervals. The values were then read and recorded.

Microbiological Analysis of Degradable Sewage Sludge Waste for Land Farming Application

Microbiological analysis of the samples involved enumeration and isolation of bacteria after three weeks of degradation in fresh unused plastic containers. Ten-fold serial dilution method was employed for the enumeration and isolation of bacteria. In this method, 1.0 ml of sample leacheate was added to 9.0 ml of sterile normal saline (diluent) to give 10^{-1} dilution. Further serial dilutions were made by transferring 1.0 ml of 10^{-1} dilution to another 9.0 ml of diluent up to 10^{-6} dilution. From the 10^{-1} dilution, 0.1 ml aliquots of samples were introduced on to the surface of sterile solid nutrient agar medium in petridisles. The inocula were spread plated using a sterile bent glass rod. The inoculated plates were incubated at 37 ºC for 24 hr, and the colonies that developed were counted and recorded, and taken as the population of bacteria in colony forming unit per milliliter (cfu/ml) leacheate of the samples.

For the purpose of isolation of

Fig. 1 % Moisture content versus time (min) for day 1

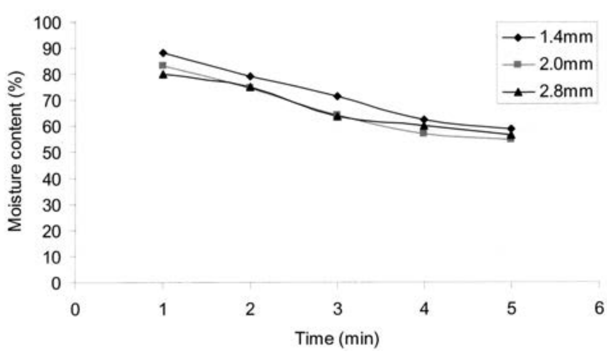
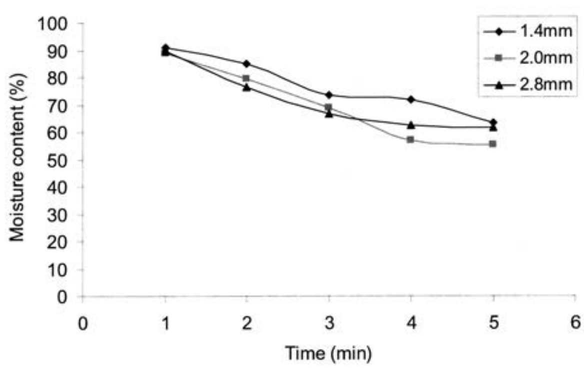


Fig. 2 % Moisture content versus time (min) for day 2



bacteria, pure cultures were obtained by subcultering discrete colonies on to fresh sterile solid nutrient agar medium, which were incubated at 37 ºC for 24 hr (APHA, 1992).

Results and Discussion

The result obtained from the research is shown in the figures in terms of moisture content effect on the characteristics of sewage sludge for land faring application.

Fig. 1, illustrates the moisture content concentration varies against time for various sizes of sewage sludge for land farming application for 1 day exposure. From **Fig. 1**, it is seen that the moisture content concentration decreases with increase in time. The order of magnitude in terms of moisture retained capacity is given as 1.4 mm > 2.0 mm > 2.8 mm.

Fig. 2, illustrates the moisture content concentration versus time for various sizes of sewage sludge for land farming application on 2 days exposure. From **Fig. 2**, it is seen that the moisture content concentration decreases with increase in time. The order of magnitude in terms of moisture content concentration is given as 0.4 mm > 2.8 mm > 2.0 mm.

Fig. 3, illustrates the moisture content concentration against time for various sizes of sewage sludge for land farming application for 3 days exposure. From **Fig. 3**, it is seen that the moisture content concentration decreases with increase in time for 3 days exposure. In day 3 there is no must significant change in moisture content concentration. The order of magnitude in terms of moisture content concentration retained capacity is given as 1.4 mm > 2.8 mm > 2.0 mm or 1.4 mm > 2.0 mm > 2.8 mm.

Fig. 4, illustrates the moisture content concentration versus temperature for different days. Results obtained showed that the moisture content concentration increases with increase in temperature. In **Fig. 4**, it is observed that the variation in moisture content concentration can be attributed to variation in temperature. The order of magnitude in terms of moisture content concentration upon the influence of temperature is given as 3 days > 2 days > 1 day. This shows that the composition of the sewage sludge for land farming application will change with number of days of sun light exposure.

Fig. 5, illustrates the moisture content concentration against time for different days of exposure. The results obtained showed that the moisture content concentration decreases with increase in number

Fig. 3 % Moisture content versus time (min) for day 3

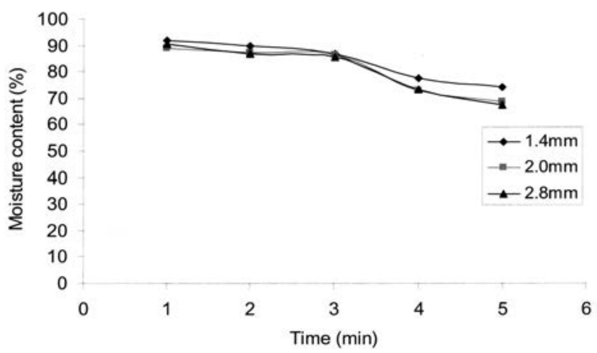


Fig. 4 % Moisture content versus temperature (ºC) for different days

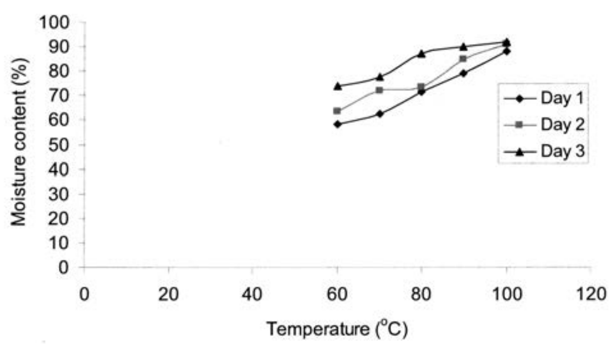


Fig. 5 % Moisture content versus time (min) for different days

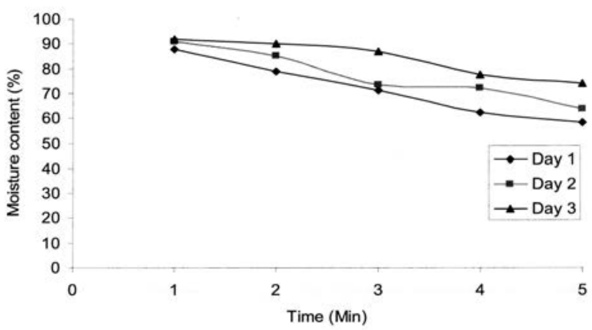
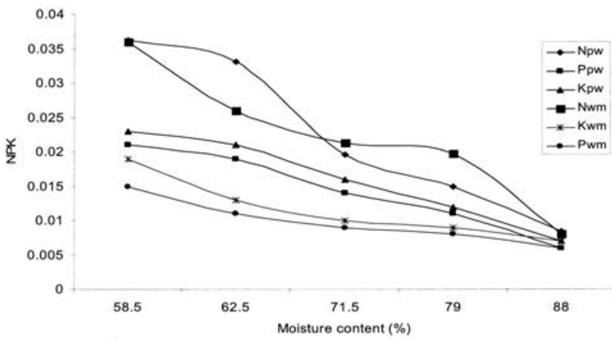


Fig. 6 NKP concentration versus % moisture content day 1 (1.40 mm) (comparism between the present and past works



of days of exposure. In **Fig. 5**, it is observed that the various in the moisture content concentration can be attributed to variation in number of days of exposure of the sewage sludge. The number of days of exposure may influence the concentration of nitrogen, phosphorus, potassium as well as the quality of the nutrient.

Fig. 6, illustrates the relationship between the moisture content concentration with nitrogen, potassium and phosphorus concentration for 1 day exposure. In **Fig. 6,** it is seen that the concentration of nitrogen, phosphorus and potassium decreases with increase in moisture content concentration for 1.40 mm mash of sewage sludge for land farming application. From **Fig. 6**, it is seen that the concentration of nitrogen is higher than phosphorus and potassium as well as potassium higher than phosphorus (N > K > P).

The concentration of nitrogen, phosphorus and potassium (NKP) for 1 day exposure of 1.40 mm mesh was compared with the previous work done by Wami (2007) on impact of moisture content concentration on NPK. The results of obtained showed 55-83 % reduction in moisture content concentration compared to the recent work presented which showed 58-88 % reduction of moisture content. The variations in the moisture content concentration influence the quality of NPK. Therefore, the results obtained from the recent investigation is the best compared to Wami (2007) proposed NPK concentration.

Fig. 7, illustrates the NPK concentration against moisture content for 1day exposure of 2.00 mm mash of sewage sludge for land farming application. Results obtained showed that NPK concentration decreases with increase in moisture content. The order of magnitude in terms of NKP concentration is given as N > K > P.

The concentration of nitrogen, phosphorus and potassium (NKP) for 1 day exposure of 1.40 mm mesh was compared the previous work done by Wami (2007) on impact of moisture content concentration on NPK. The results of obtained showed 54.50-83 % reduction in moisture content concentration compared to the recent work presented which showed 49-80 % reduction of moisture content. The variations in the moisture content concentration influence the quality of NPK. Therefore, the results obtained from the recent investigation is the best compared to Wami (2007) proposed NPK concentration.

In **Fig. 8**, it is observed that the NPK concentration of sewage sludge waste decrease with increase in moisture content. The variation

Fig. 7 NKP concentration versus % moisture content day 1 (2.00 mm) (comparism of the present and past works)

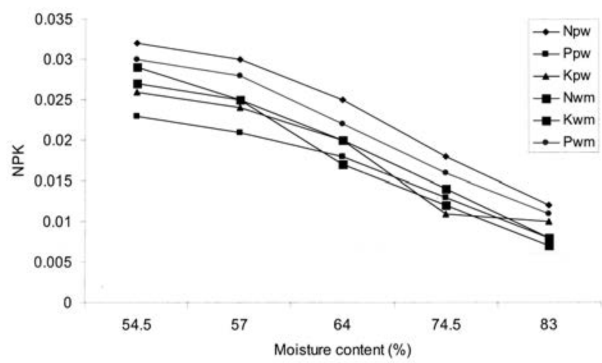


Fig. 8 NKP concentration versus % moisture content day 1 (2.80 mm) (comparism of the present and past works)

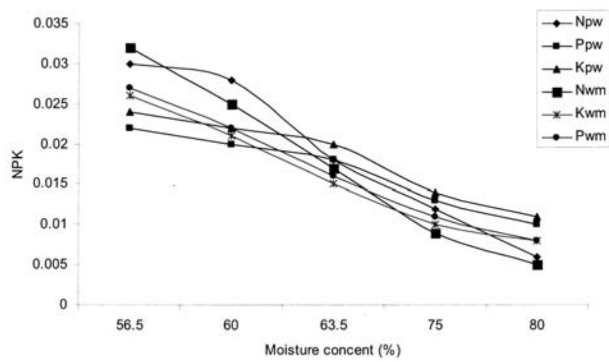


Fig. 9 NKP concentration versus % moisture content day 2 (1.40 mm)

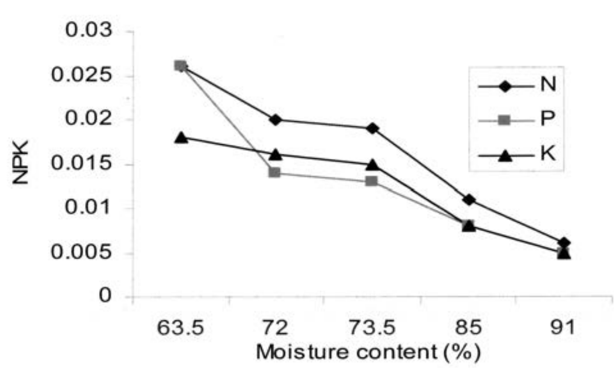
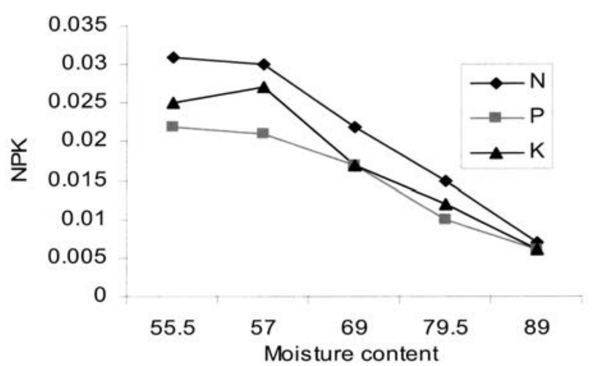


Fig. 10 NKP concentration versus % moisture content day 2 (2.00 mm)



in the concentration of NPK can be attributed to the variation of moisture content for 1 day exposure to sunlight of 2.80 mm mash to sewage sludge waste. The order of magnitude in term of NKP concentration is N > K > P and attain an intercept at a range of 60 to 61.5 % moisture content concentration.

The concentration of nitrogen, phosphorus and potassium (NKP) for 1 day exposure of 1.40 mm mesh was compared the previous work done by Wami (2007) on impact of moisture content concentration on NPK. The results of obtained showed 56.50-80 % reduction in moisture content concentration compared to the recent work presented which showed 53.10-80 % reduction of moisture content. The variations in the moisture content concentration influence the quality of NPK. Therefore, the results obtained from the recent investigation is the best compared to Wami (2007) proposed NPK concentration.

Fig. 9, illustrates the NKP concentration upon the influence of moisture content. From **Fig. 9**, it is seen that the NKP concentration of sewage sludge decreases with increase in moisture content for 2 days exposure of 1.40 mm mesh. The order of magnitude in terms of NKP concentration is given as N > K > P with the concentration of N = P at NKP concentration of < 63.5 %. Similarly, the concentration of P was equal to K concentration at NKP = 0.0155 mol % and moisture concentration of < 72 % for a mesh size of 1.40 mm.

In **Fig. 10**, it is observed that the NKP concentration of sewage sludge for land farming application increases as well decreases with increases in moisture content concentration for 2 days exposure of 2.0 mm mesh sample. The variation in the concentration of NKP can be attributed to variation in the concentration of the moisture content. The order of magnitude in terms of NKP concentration is given as N > K > P within the range of 55.5 to 58.0 % of moisture content and above the range yield N > P > K fro 2 days exposure of 2.00 mm sewage sludge samples for land farming application.

From **Fig. 11**, it is seen that the NKP concentration decreases with increase in moisture content concentration, except at 67.5 % where there is a sudden change in the phosphorus (P) concentration with a rapid increase for 2 days exposure of 2.00 mm mesh of the sewage sludge for land farming application. The variation in the NKP concentration can be attributed to the variation in moisture content concentration as well as number of days of exposure of sewage sludge. The order of mag-

Fig. 11 NKP concentration versus % moisture content day 2 (2.80 mm)

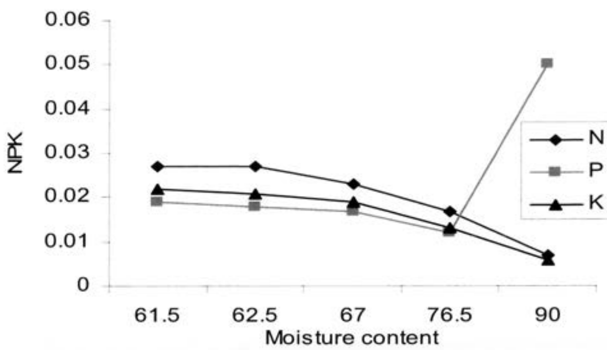


Fig. 12 NKP concentration versus % moisture content day 3 (1.40 mm)

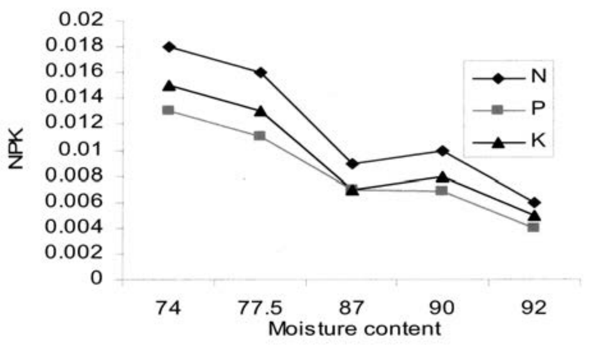


Fig. 13 NKP concentration versus % moisture content day 3 (2.00 mm)

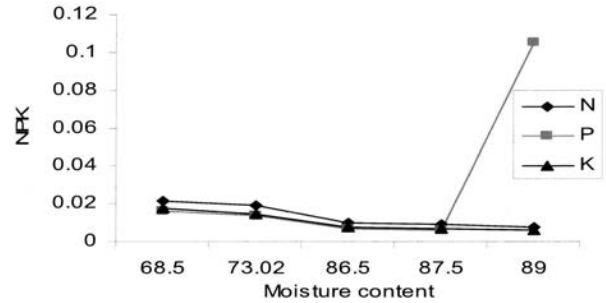
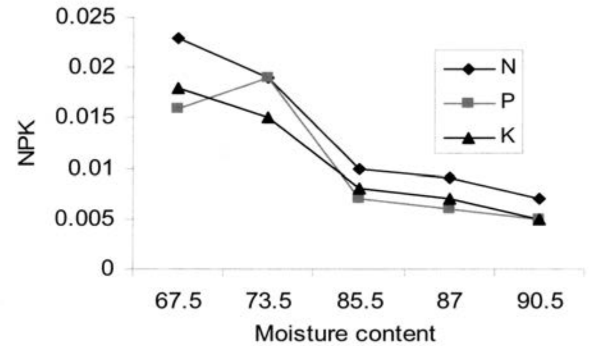


Fig. 14 NKP concentration versus % moisture content day 3 (2.80 mm)



nitude in terms of NPK concentration is given as N > K > P at a range of 61.5 to 76.5 % above this point the order of magnitude in terms of NPK concentration is P > N > K for 2 days exposure of 2.00 mm mesh of sewage sludge.

In **Fig. 12**, it is observed that the NPK concentration decreases with increase moisture content concentration for 3 days exposure of 1.40 mm mesh of sewage sludge. From **Fig. 12**, a uniform curve was observed at 87.0 % moisture content with various NPK concentrations. It is seen from **Figs. 4**, **12**, N > K > P in terms of order to magnitude of NPK concentration. The variation in the NPK concentration can be attributed to the variation in moisture content concentration as well as mesh size of the sewage sludge.

From **Fig. 13**, it is seen that the NPK concentration decreases with increase in moisture content concentration for 3days exposure of 2.00 mm mesh of sewage sludge for land farming application, within the range of 68.5 to 87.5 % of moisture content and above this range the phosphorus (P) concentration increase with increase in moisture content concentration. The variation in the NPK concentration can be attributed to the change in the moisture content concentration, mesh size and the period of exposure.

In **Fig. 14**, it is seen that the concentration of phosphorous (P) increases with in moisture content within the range of 0 to 73.5 % and above the range, a sudden decreased in phosphorus (P) concentration was observed with increases in moisture content concentration. Similarly, the concentration of N and K decreases with increases in moisture content concentration. The variation in NPK concentration can be attributed to the variation in the moisture content concentration, size of mesh and period of exposure.

Conclusion

The following conclusions were made from the results:

1. Percent moisture content effected concentration on the NPK concentration quality.
2. Most of the sewage sludge waste after reduction in the moisture content and other impurities through period of exposure and application of heat may improve the NPK concentration as well as improved suitability for land farming application.
3. The sunlight application into the sewage sludge was effective to reduce the moisture content concentration below 50 %. This means that the exposure of sewage sludge into sunlight before land farming application was quite encouraging as compared to the NPK concentration after drying at various operating temperature.
4. Proper sewage sludge sampling is critical to obtain accurate NPK recommendation. Timely NPK application and incorporation into the soil are important factors in correcting and managing soil polluted with impurity. The first step in the application of NPK content obtained from sewage sludge and their effect on growth rate of crop is to be identified. Decrease in the growth rate of crop may indicate the percentage increase in moisture content concentration. With careful sampling of fields, soil tests can determine the extent and severity of improved sewage sludge component for land farming application. The growth rate of the crop responds to improved soil with sewage sludge waste.

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21-23 September, 2011, Klassis REsort Hotel, Istanbul, Turkey
http://trakageng2011.nku.edu.tr/

• CIGR-AgEng 2012, International Conference of Agricultural Engineering
8-12 July, 2012, Valencia, Spain
http://www.ageng2012.org/

• Sustainable Bioproduction—Water, Energy, and Food
19-23 September, 2011, Tokyo, JAPAN
Sponsored by SCJ, JAICABE & CIGR
http://www.cigr2011.org/

CIGR2011 will be held as scheduled.

First of all, we sincerely thank you for your prompt and kind inquiry after us. Tens of thousands of people were killed or rendered houseless by the most disastrous earthquake and tsunamis which hit the area of Northeastern Japan on the 11th of March, 2011. And what is worse, serious damages happened to the nuclear power station.

Fortunately, there was limited damage to most of our members and our workplaces. Due to this, it is pleased to inform you that we will definitely hold the CIGR International Symposium 2011 (WEF 2011) in Tokyo according to schedule, 19-23 September 2011.

We are looking forward to seeing you all in Tokyo in the coming September.

April 5, 2011

Prof. Taichi Maki,
Chair of the National Organizing Committee of WEF 2011
Prof. Takemi Machida,
President of the Japan Association of Agricultural and Biosystems Engineering

Development and Evaluation of Betel Leaf Conditioning Chamber



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Abstract

A betel leaf conditioning chamber was developed with heating and cooling arrangement to achieve an environment of desired temperature and relative humidity for conditioning of betel leaves. The performance of conditioning betel leaves in the conditioning chamber was compared with traditional vat based on sensory and biochemical aspects. Use of a water cooling system for a short period followed by heating gave better results than the other combinations tried in the experiment. The biochemical studies on the conditioned leaves obtained from the vat, as well as from the mechanical conditioning systems, indicated that there was not much variation in the biochemical qualities of the leaves among different treatments. Though the percent conditioned leaves obtained from conditioning chamber was less than that from traditional vat, the process was quicker. Further, the chamber could be used in the rainy season when the traditional vat does not operate. The studies on the conditioning chamber indicated that the chamber performed better as the environment inside the chamber could be manipulated to the desired level.

Introduction

Betelvine, commonly known as Pan (*Piper betle* L.) is a perennial, dioecious, evergreen creeper grown in moist, tropical and sub-tropical regions of India. A large number of small and marginal farmers solely depend on betelvine cultivation for their family maintenance. It is not only a local consumable commodity but also is exported to other states of India and abroad (Rayaguru *et al*., 2007). Betel leaf is a bit sour in taste but is a popular mouth freshner. They are usually used as masticatory, stimulant, digestive, antiflatulent, anti-inflammatory and pain reliever. Betel leaves are used as several common household remedies (Chattopadhyay *et al*., 1984; Mishra 1992; and Venkatrao *et al*., 1977). In addition to the above medicinal value, the betel leaves also have a good nutritional value.

An extensive survey indicated that a greater percentage of betel leaves in the state were used for conditioning. Conditioning is a process in which the green colour of the leaves is changed to yellow/white which is highly demanded by a group of consumers. The biochemical composition of the green and conditioned leaves (Rayaguru *et al*., 2004) inferred that there was virtually no change in moisture, protein, carbohydrate and total ash content during conditioning of betel leaves, where as, the reduction in fat could be noticed. During conditioning the chlorophyll and essential oils were drastically reduced. The tannin and fibre content of the conditioned leaves were remarkably lower than those of green leaves. The changes observed might be acting as influencing parameters for the high consumer demand for a specific group.

Conditioned leaves have high commercial value. The process of conditioning of betel leaves not only enhances the taste but also increases

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the storability of the leaves to a noticeable extent. Moreover, the cost of such conditioned leaves is much higher than the general unprocessed ones and, thus, earns more profits to the growers. It also provides employment to rural people throughout the year.

Materials and Methods

Conditioning by Traditional Vat

To preserve the delicacy of the betel leaves for days together, they are artificially ripened or bleached before transportation or storage. The betel leaves are traditionally conditioned using a vat made of brick, clay and bamboo strips (Rayaguru *et al*., 2007). Enough care is taken to make it air tight, as well as insulated, by restricting the opening of the door. Inside the vat, bamboo racks are provided at a height of 30 cm from the ground level at an interval of 45 cm to 60 cm between the racks. After removing the petioles, the leaves are bundled into 50 to 100 in number and are arranged in the baskets in a specific way. Heat is generated inside the vat by burning charcoal in a traditional chullah in one corner of the room. After heating, the leaves are subjected to a cooling period of about 36 to 72 h phasewise both inside and outside the chamber depending on the atmospheric weather conditions. During the cooling period the leaves are sorted and reshuffled (by keeping the top layers at the bottom and the bottom layers on top). Before subjecting the baskets to second phase of charging, the damaged or rotten leaves are discarded. Then the process is repeated 3 to 4 times till all the leaves are conditioned i.e., the green colour of the leaves gets changed to yellow colour.

It has been observed that during the rainy season the traditional vat does not give satisfactory results. It may be due to the frequent fluctuation in the atmospheric conditions. Sometimes the processors incur heavy loss because of this. Hence, usually the traditional vats remain closed during this period. Therefore, a conditioning chamber was developed in which an environment of desired temperature and relative humidity could be created. The performance of conditioning betel leaves in the conditioning chamber was also compared with traditional vat.

Development of Conditioning Cham-ber

A conditioning cum cooling unit was designed and developed (**Figs. 1-2**) to achieve an environment of desired temperature and relative humidity in which the betel leaves are to be processed. The unit consisted of a blower, heater, water tank, pump and evaporative pads. Aluminium racks were provided to be used as conditioning space for betel leaves. Around 16,000 to 20,000 leaves can be conditioned at a given time. In the operation, the blower sucked the ambient air, which was then conditioned as per the requirement. The heaters were connected through a thermostat and variac to regulate the air temperature. The evaporative/cooling pads increased the humidity through a continuous supply of water from the top through nozzles by a water pump (**Fig. 1**). Cooling of air was done at the time of requirement. The use of heater and evaporative pad depended upon the temperature and humidity requirement of the conditioned air. The main function of the chamber was to provide heat and humidity to the conditioning air when required. The outside walls of the entire unit were provided with insulation of black foam material. At the back of the blower a projected plenum chamber was joined in order to reduce the open space to outside atmospheric conditioning (**Fig. 2**). Provisions were made for the recirculation of water to the evaporative pad for continuous operation of the unit. The temperature and relative humidity profile in a traditional vat and conditioning chamber were studied.

Conditioning of Betel Leaves

Fresh, healthy and matured betel leaves from the farmers' field (Balibaraj) were collected in bulk and washed thrice thoroughly in clean

Fig. 1 Schematic diagram of betel leaf conditioning chamber

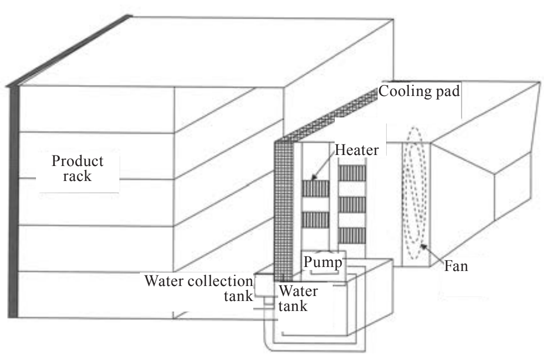
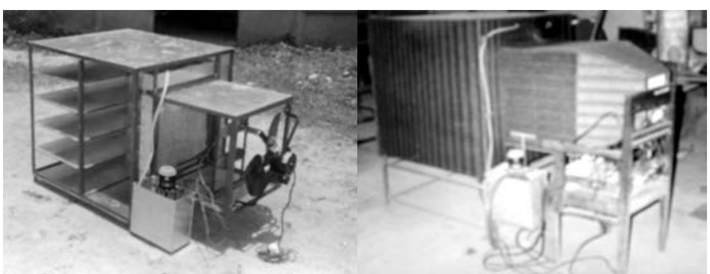


Fig. 2 Betel leaf conditioning chamber (inside and outside view)



cool water to remove the dirt and dust present. Then the petioles were removed.

In the process of conditioning, the green colour of the leaves get changed to yellow, which is due to the thermal stresses developed in the leaves without loss of moisture as a result of alternate heating and cooling. Hence, in order to test the individual and combined effect of heating and cooling based on provisions made in the chamber, the experiments were carried out as described below.

A. Independent conditions
1. vat
2. 6 h heating followed by atmospheric cooling (24 h)
3. 6 h heating followed by evaporative cooling (12 h)
4. Both heating and cooling for 6 h followed by atmospheric cooling (24 h)

B. Dependent parameters
1. Time of conditioning
2. Percentage yellow leaves
3. Percentage green leaves
4. Percentage rotten leaves
5. Biochemical parameters

The leaves were loaded onto the racks of the chamber in multiple bundle layers. For each condition, the conditioned leaves were examined for physical changes like colour intensity (% yellow leaves) and damage intensity (% rotten leaves). Percentage rotten leaves were used as indices of decay upon daily inspection. Rotten percent was calculated using the number of rotten leaves divided by the total number of leaves per treatment. Generally black spots, over softening and mold growth were used as indices of rotting. The leaves showing decay signs were recorded and removed from the stored samples.

The leaves in which more than 80 % of the green colour was converted to yellow colour were recorded as conditioned leaves. The conditioned leaves were subjected to sensory evaluation for freshness and taste. Corresponding quality analysis was made for the conditioned leaves obtained from the traditional vat type conditioning units as control samples. The fresh and conditioned leaves were analysed for different biochemical qualities such as moisture content, pH, total sugar, ascorbic acid, chlorophyll and volatile oil content using standard procedure (AOAC, 1984; Ranganna, 1986).

Results and Discussion

Temperature and Relative Humidity Profile

The hourly temperature and relative humidity profile of the traditional vat and the developed chamber under no load conditions with various operational adjustments are presented in **Figs. 3** and **4**.

From **Fig. 3**, showed that the temperature increased at a higher rate in the vat for the first 3-4 h, remained at that value for about 2 h and then started decreasing gradually for the next 5-6 h to reach nearly to the atmospheric conditions. In case of the conditioning chamber (cooling system 'off') the temperature increased rapidly up to 5-6 h and then the rate of increase decreased. But with the cooling system 'on' the chamber gave a different profile for temperature. The increase was not very high though it showed an increasing trend initially and after 5-6 h it remained almost constant.

Similarly, the hourly profile of relative humidity is presented in **Fig. 4**. The relative humidity of the vat reduced initially up to 2-3 h just after charging but then, gradually, the value of relative humidity increased and maintained almost the same value. The conditioning chamber with cooling system "off" showed a more or less similar trend to that of the traditional vat. But, with the cooling system "on", the relative humidity increased rapidly initially (3 to 4 h) and then maintained a con-

Fig. 3 Temperature profile in vat and conditioning chamber

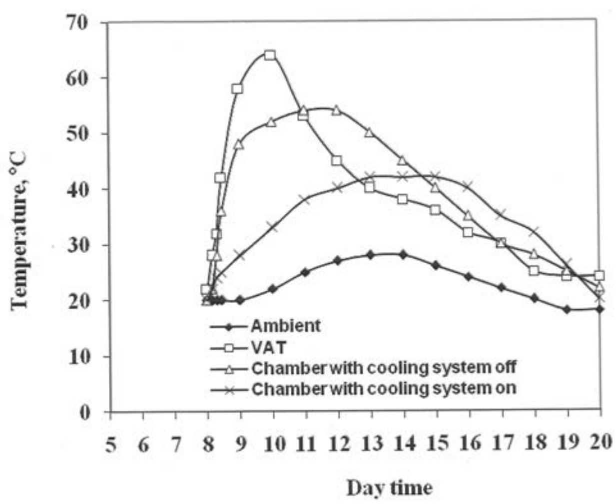
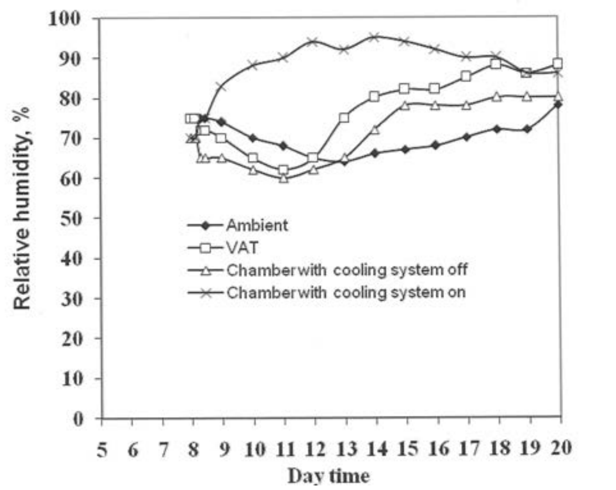


Fig. 4 Relative humidity profile in vat and conditioning chamber



stant value.

Comparative Study of Conditioning of Betel Leaves

The percentage leaves conditioned under various heating and cooling conditions from each experiment and corresponding observations is presented in **Table 1**. The percent rotten leaves and percent green leaves are 20-25 % and 2 %, respectively, in the case of the traditional vat system. But, it is time consuming and the labour requirement was quite high. Among the different operational adjustments by the mechanical system, the heating followed by atmospheric cooling (condition 1) gave best results. Energy consumption was also much less as compared to those of other systems. However, it took a longer time and a wet cloth covering was required throughout to maintain the freshness of the leaves. Otherwise the percent dehydrated leaves increased. In the case of the other two systems given in **Table 1** with the use of heating followed by evaporative cooling system (condition 2), the process of conditioning was quicker. But the percent rotten leaves were relatively higher. This was more so in case of both heating and evaporative cooling (condition 3) than that in condition 1. This was probably due to the pooling of water observed on the surface of leaves as a result of higher humidity during the operation of the evaporative cooling system. Hence, it may be inferred that the use of a water cooling system for a short period after heating may give better results and, in that case, power consumption will also be less. Though the percent conditioned leaves obtained from conditioning chamber was less, it could be used in the rainy season when the traditional vat was closed.

Biochemical Qualities of Conditioned Leaves

The biochemical studies on the conditioned leaves obtained from vat as well as from the mechanical conditioning systems are presented in **Table 2**. The data indicated that there was not much variation in the bio-chemical qualities of the leaves among different treatments. In general, there was not much change in proximate compositon (protein, fat and carbohydrate) except in fibre which was reduced to about 60 % that of green leaves. Sehgal *et al.* (1975) concluded the similar inference for proximate composition of some leafy vegetables. Among biochemical qualities, moisture content, TSS, pH and ascorbic acid did not show any variation. But significant effect was observed in chlorophyll content, tannin and essential oil content. Similar observation has been observed by Rayaguru *et al.*, 2004. Venskatonis (1997) and Singh *et al.* (1990) found similar changes under various treatment of betel leaves and other materials. However, this variation was not significant among the sapmles obtained from different treatments. This indicated that the method of conditioning did not have any effect on quality of the leaves. Therefore the percent of yellow leaves and time of conditioning

Table 1 Comparative conditioning study in different systems

System	Time of conditioning, days	% yellow leaves	% green leaves	% rotten leaves	% dried leaves	Remarks
VAT	10-12	70-75	2	20-25	0	Time and labour consuming
Only heating (6 h) + atmospheric cooling 24h (condition 1)	7-8	75-80	5	20-25	2	Time consuming, wet cloth covering needs to be used
Only heating 6 h + evaporative cooling 12 h (condition 2)	3-4	60-65	10	28-30	5	Water deposition on few leaves of upper layer
Both heating and cooling system on for 6 h + atmospheric cooling 24 h (condition 3)	5-6	50-60	5	30-40	0	Water deposition on the leaves causing rotting, Desired temperature was not obtained

* "+" indicates followed by

Table 2 Biochemical and proximate analysis of betel leaves conditioned in different systems

Quality parameters	Green leaves	Vat	Condition 1	Condition 2	Condition 3
m.c. (% wb)	87.68	87.05	87.82	86.75	88.42
TSS, % Brix	4.0	4.8	4.8	5.2	4.7
pH	4.0	4.5	4.5	4.5	5.0
Chlorophyll (mg/100 g)	72.5	8.9	7.8	8.6	9.2
Ascorbic acis (mg/100 g)	76.9	85.5	88.2	86.6	85.2
Protein, %	2.40	2.48	2.41	2.40	2.36
Fat, %	0.80	0.50	0.58	0.61	0.48
Carbohydrate, %	5.80	5.50	5.2	5.6	5.0
Fibre, %	2.30	1.40	1.42	1.45	1.6
Tannin (mg/100 g)	700	110	105	106	102
Essential oil (mg/100 g)	280	70	64	72	60

could decide the suitability of the method.

Conclusion

Use of a water cooling system followed by only heating for few hours gave better result. Due to reduction in cooling period, the total time requirement was also less. The quality analysis of the conditioned leaves obtained from the vat as well as from the mechanical conditioning systems indicated that there was not much variation in the bio-chemical qualities of the leaves among different treatments. Though the percent yellow leaves obtained from conditioning chamber was less, it could be used in the rainy season when the traditional vat was closed. Overall studies on the conditioning chamber indicated that the chamber performed better since the environment inside the chamber could be manipulated to the desired level.

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ABSTRACTS

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

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Seed Cotton Feeding to Double Roller Gins in Modernized Ginneries—A Study: **S. K. Shukla**, Scientist (Sr. Scale, Mech. Engg.) Ginning Training Centre of Central Institute for Research on Cotton Technology (CIRCOT) ICAR, Nagpur-440 023 INDIA; **V. G. Arude**, same; **Jyothi M. Nath**, same.

Seed cotton feeding systems employed to feed seed cotton to DR gins in modernized Indian ginneries have been thoroughly studied in the present study. The feeding systems were compared on the basis of productivity loss and power requirements. Productivity of first, central and end gins with system feeding in a row were compared to manual feeding. Different type of seed cotton feeding systems resulted in productivity loss of 2.7 to 9.6%. Among all systems studied, trolley feeding-single side (6 DR gins/trolley) was found the best followed by trolley feeding system-either side (8 DR gins/trolley) for productivity of DR gins. In case of screw conveyor feeding system, minimum productivity loss was observed for 9 DR gins. Power requirement/DR gin for different kind of feeding systems varies from 0.5 to 1.8 hp. Minimum power requirement was observed for trolley feeding system-either side with 18 DR gins/trolley whereas maximum power requirement was observed for trolley feeding system-single side with 6 DR gins/trolley.

Soaked and Non-Soaked Drying Methods for Vanilla (*Vanilla Planofilia L.*)

by

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Abstract

Vanilla (*Vanilla planifolia L.*) belongs to most deserved and important cash-crops in tropical regions. This paper presents the results of testing basic methods of vanilla processing, especially drying and storage. There are well known problems related to mechanical properties while processing and storing. The effects of soaked and non-soaked, conventional drying methods were observed for vanilla. Thus, this paper is focused on equations describing drying behaviors of the material under those two methods. Equations with high confidence intervals were found for describing the drying process. Reducing weight loses while conserving the quality of vanilla will have positive effects for farmers and producers. Results of this study showed that the soaked drying method for vanilla was much better than the non-soaked drying in terms of drying period, energy saving and product quality.

Introduction

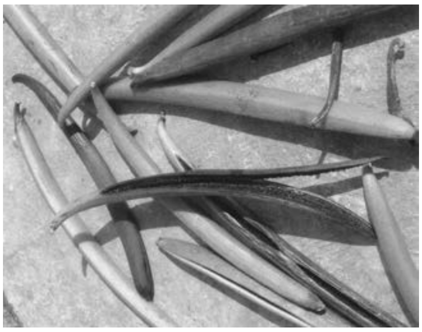
Vanilla belongs to the family (orchidaceae), one of the largest families, including about seven hundred genres and 20,000 species. Orchids are the most popular family representatives, giving beautiful and desired blossoms. Vanilla is only one orchid used in the food industry. There are 110 to 150 cultivars and kinds of vanilla (Gassenmeier *et al.*, 2008).

Mexican origin vanilla (Vanilla planifolia), nowadays, is widely grown on Madagascar and surrounding areas. This kind of vanilla has the highest vanillin content. Some of the Mexican origin vanillas have a predicate: "Bourbon" vanillas, characterized by slender and long pods. The pods contain lots of small black seeds; have a strong and oily skin and a strong aroma. Original Mexican kinds have rather full and spicier aroma with wooden fragrance traces (Bythrow, 2005 and Mhadji, 2008).

The typical vine of vanilla grows in a tropical belt, characterized by frequent and rich rainfall, high temperatures and humidity. The best soil for growing vanilla is a light, sandy-loam soil, well drained and pervious mould. Vanilla could not stand low temperatures, even short term freezes are fatal. Vanilla is best to be grown under the canopy of rainforest giants providing desired shade, same as the cocoa tree and, for its growth, needs supporting poles or other trees in order to climb upon it. Every year the vanilla farmers bend vanilla stems to be straight and to keep stems at the same height in order to make the harvest easier—(Dnyaneshwar *et al.*, 2009).

Pods appear right after blooming that are mature between the sixth and ninth months after pollination. If the pods are left on the plant,

Fig. 1 Vanilla Pods



their color changes to light green: a mark of full ripe, and later the tip of pod becomes light. Finally the pod opens along the lengthwise axis and rows of small, black seeds are fully exposed. In this phase, pods are scented by their typical vanilla aroma; however, further processing is unusable. Pods must be harvested prior to opening. Immediately after the harvest, pods are separated from the clusters and sorted by size. Pod size is a main indicator of quality. Longer pods have higher vanillin and aromatic substances content. Shorter pods have vanillin content much lower, are not really desired and are mostly used for vanilla powder production (Gassenmeier *et al*., 2008).

In this study, the soaked and non-soaked drying methods for vanilla have been investigated. Results showed that the soaked drying method for vanilla had better parameters in terms of drying time and energy savings.

Materials and Methods

The vanilla pods were obtained from a North Sumatra province in Indonesia. The region has very good-quality soils with average temperatures fluctuating between 18 and 34 ºC and air humidity between 79 to 96 % (average of 82 %), while annual rainfall range was 1,100 to 3,400 mm.

Twenty kg of freshly harvested *Vanilla planifolia L*. were used for this experiment. Immediately after the harvest the pods were separated from the clusters and sorted by sizes and divided into halves (**Fig. 1**). Total weight of soaked samples was 10 kg and the weight of non-soaked samples was the same. Half of the pods were soaked by water having a temperature of 63 to 65 ºC. Halve of the pods were placed on a dark sheet and sun dried for two hours, while unusable pods (infected, mechanically damaged, etc.) were displaced. Later on pods were bonded together in clusters of 20 pieces (half of the clutters were from soaked pods and half from non-soaked pods) covered by a fabric sheet and, for each cluster, the weights were recorded every day. The pods were placed in the boxes and were dried on wooden grids in a well ventilated room with air temperatures about 35 ºC and relative humidity of about 70 %. Pods changed color from green to dark brown. Meanwhile, lengthwise oriented wrinkles and folds appeared. At this time, the pod could be bent and then return to its previous shape without damage. Time of drying was dependent on the pods' sort and was a significant factor during the aroma development.

Moisture content of the samples was determined by ASTA drying method (Olaniyan and Oje, 2002).

Results

The sort quality was set up by International Federation of Agricultural Producers (Mhadji, 2008). The average amount of pod length and soaking time are described in **Table 1**.

The measured values obtained through the drying test are displayed in the diagrams below, from **Figs. 2** to **5**. Their weight distribution, drying periods and average weight of dried samples are given in **Table 2**, and average moisture content in **Table 3** below.

Table 1 Soaking time of vanilla pods (Gassenmeier *et al*., 2008)

Sort-Quality	Pods length, cm	Soaking time, min
I	≥ 15	4
II	10-15	3
III	10	2
IV	broken pods and remains	1.5

Table 2 Vanilla pods weight distribution and their weight loss by drying

Pods sort	Average weight of the sorted samples, g	Time of drying, days		Average weight of dried sample, g	
	m_O	T		m_1	
		soaked	non-soaked	soaked	non-soaked
I	1,900	28	59	725	718
II	3,400	23	44	1,298	1,294
III	3,100	20	42	1,229	1,191
IV	1,600	5	13	641	579

Table 3 Vanilla pods average moisture content

Pods sort	Average moisture content before drying , %		Average moisture content after drying, %	
	mc_{bd}		mc_{ad}	
	soaked	non-soaked	soaked	non-soaked
I	72	74	24	22
II	70	69	26	28
III	71	72	33	32
IV	70	73	34	36

The average weight of dried samples was the weight of samples after drying with residual weight between 36-40 % of the average weight of the sorted samples before drying (Gassenmeier *et al*., 2008). This interval was set by the International Federation of Agricultural Producers (Mhadji, 2008).

The differences among the average weight and moisture content of soaked and non-soaked dried samples were compared by the statistical F test and found not statistically important with a value of reliability 95 % (Freedman *et al*., 2007).

The measured values were interleaved by means of regression a cotangent curve for non-soaked pods and an exponential curve for soaked pods (**Fig. 2**). To interleave the data, the genfit function of the Mathcad 14 software (Pritchard, 1999) was used. The function employed the Levenberg-Marquardt algorithm (Marquardt, 1963; Lourakis, 2005) that provided a numerical solution to the problem of minimizing a function deviation, generally nonlinear, over a space of parameters of the function. The dependency above could be described with a regression curve, where m was the weight of the samples (kg) marked by subscripts, n for non-soaked pods, u for soaked pods, I, II, III, IV for sort quality, and t was the time of day. The coefficients of determination R^2 were also determined for every regression curve. These coefficients were marked by the same subscripts as the regression curves.

The dependencies between weight of a dried sample, drying time and coefficients of determinations for sort quality I vanilla pods are described by **Eqns. 1** and **2**. Measured amounts and regressions curves are displayed in **Fig. 2**, below.

$$m_{nI}(t) = 4.752 \times 10^{-2} \times acot\,g\,(0.1 \times t - 2.8) + 5.7 \times 10^{-2},\ R_{nI}^2 = 0.9921 \quad (1)$$

$$m_{uI}(t) = 5.7 \times 10^{-2} \times e^{1.2 \times \{1/(t+1)\}^{0.48}},\ R_{nI}^2 = 0.9979 \quad (2)$$

Vanilla pods-sort quality II, dependencies between weight of dried sample, drying time and coefficients of determinations are described at **Eqns. 3** and **4**. Measured amounts and regressions curves are displayed in **Fig. 3**.

$$m_{nII}(t) = 9.402 \times 10^{-2} \times acot\,g\,(0.11 \times t - 1.43) + 10.2 \times 10^{-2},\ R_{nII}^2 = 0.9965 \quad (3)$$

$$m_{uII}(t) = 0.102 \times e^{1.2 \times \{1/(t+1)\}^{0.5}},\ R_{nII}^2 = 0.9985 \quad (4)$$

Vanilla pods—sort quality III, dependencies between weight of dried sample, drying time and coefficients of determinations are described at **Eqns. 5** and **6**. Measured amounts and regressions curves are displayed

Fig.2 Drying of vanilla pods, sort I

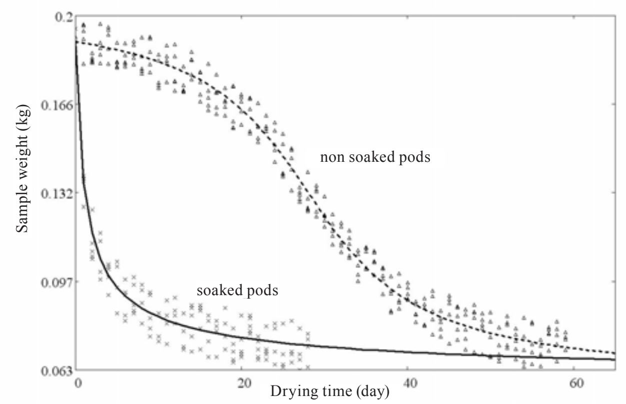


Fig. 3 Drying of vanilla pods, sort II

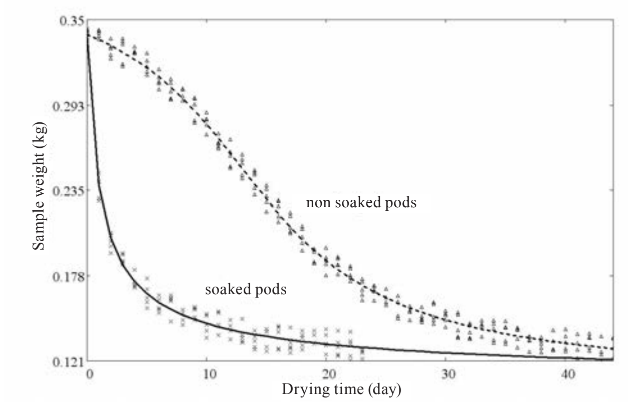


Fig. 4 Drying of vanilla pods, sort III

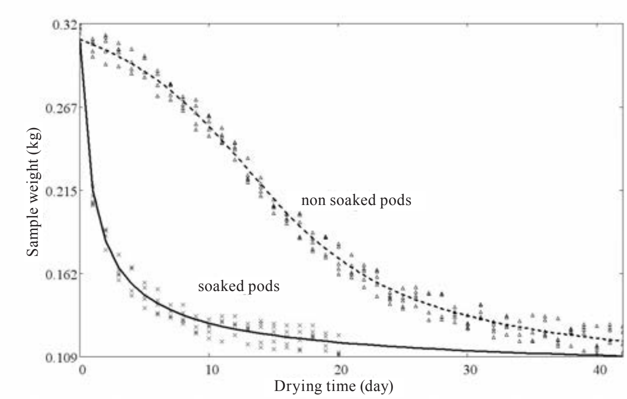
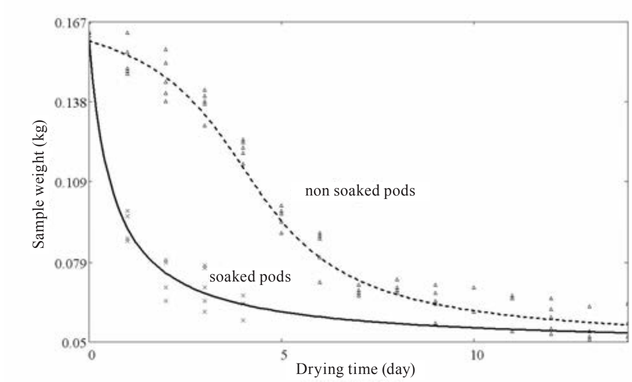


Fig. 5 Drying of vanilla pods, sort IV



in **Fig. 4**.

$m_{nIII}\ (t) = 8.572 \times 10^{-2} \times acot\ g\ (0.11 \times t - 1.43) + 9.3 \times 10^{-2}, R_{nIII}^2 = 0.9978$ ....(5)

$m_{uIII}\ (t) = 9.3 \times 10^{-2} \times e^{1.2 \times \{1 / (t + 1)\}^{0.53}}, R_{nIII}^2 = 0.9986$ ....(6)

Vanilla pods—sort quality IV, dependencies between weight of dried sample, drying time and coefficients of determinations are described at **Eqns. 7** and **8**. Measured amounts and regressions curves are displayed in **Fig. 5**.

$m_{nIV}\ (t) = 4.182 \times 10^{-2} \times acot\ g\ (0.5 \times t - 2.0) + 4.8 \times 10^{-2}, R_{nIV}^2 = 0.9996$ ....(7)

$m_{uIV}\ (t) = 4.8 \times 10^{-2} \times e^{1.2 \times \{1 / (t + 1)\}^{0.89}}, R_{nIV}^2 = 0.9935$ ....(8)

Discussion

From the measured values of weight loss, depending on the time of drying, it was clear that drying time of soaked samples for sorts I, II and III were relatively shorter than the non-soaked samples for the sorts but, for sort IV, the drying time of soaked samples was longer than the non-soaked samples of sort IV. Quality of sort IV was worse than in other sorts, the pods were broken and damaged and this negatively affected the drying time. Similar conclusions were obtained by many authors who carried out drying experiments with different agricultural products (Lahsasni *et al*., 2004; Simal *et al*., 2005; Gornicki and Kaleta, 2007).

When the percentage weight loss, depending on time, is described graphically, the resulting weight of dried vanilla is on an interval between 36-40 %, as described before. For example, the pods with weight smaller then 36 % are over-dried. Optimal intervals of drying periods for the sorts in both drying methods are given in **Table 4**. Determined dependencies and optimal drying times are shown in **Figs. 6** and **7**.

As seen from the figures, sort II and III of non-soaked pods have a very similar drying characteristic and for this reason they can be considered as one sort.

Drying characteristics were determined with a very high correlation coefficient (values around 0.99). Some parameters as drying speed, drying acceleration and drying acceleration gradients could be determined by mathematical treatment of derivative curves, which were necessary to optimize the drying process with the maximum possible energy efficiency of drying. The resulting weight of vanilla and their moisture contents were found to be same in soaked and in non-soaked drying.

There are some conflicting results in scientific papers on the use of the soaked and non-soaked drying method. Usually it has been stated that the soaked drying method increases the nutritional value of the fruit and destroys unfit enzymes, lectins and phytates present in the pods. Non-soaked drying can also reduce the emergence of alpha toxin. But this method of drying may over-dry pods and, thus, result in a large loss of flavor and rapid reduction of the resulting quality of the pods (Sreedhar *et al*., 2009). It is also published that this type of drying can more affect the extraction of vanillin (Dnyaneshwar *et al*., 2009) and the resulting flavor and aroma of vanilla (Gassenmeier *et al*., 2008). Assessment of the resulting aroma and taste is subjective and depends directly on the requirements and habits of the consumer. The decision to use a single type of drying also depends on the type of use of the dried pods, medicine, cosmetics, food industry. etc. (Karas *et al*., 1972; Anklam *et al*., 1996; Bythrow, 2005).

Table 4 Optimal drying period of vanilla pods

Pods sort	Optimal drying period T_{opt} (days)	
	soaked non-soaked	soaked non-soaked
I	20-51	52-69
II	17-43	40-52
III	14-36	40-52
IV	11-24	9-13

Fig. 6 Percentage residual weight of soaked pods

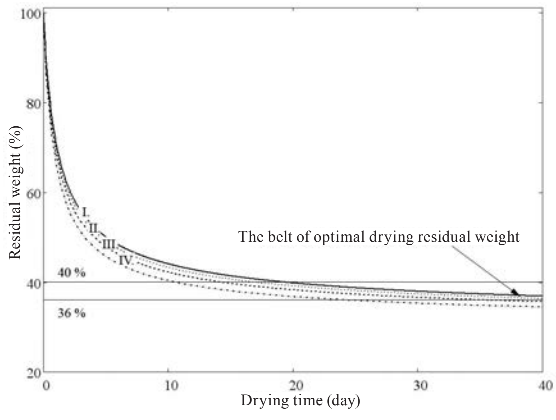
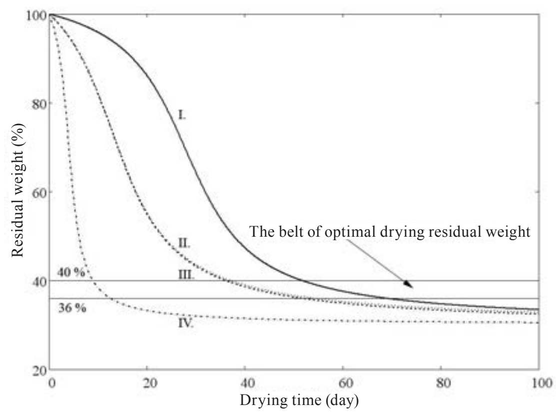


Fig. 7 Percentage residual weight of non-soaked pods



Conclusion

The experiment has proven, that soaking of freshly harvested pods significantly (95 % statistical importance) influenced the period of drying. It was apparent that the difference in drying periods between soaked and non-soaked pods was relatively high, generally about 50 % (**Table 4**). The achieved minimum drying time was 20 days for soaked pods in sort I and maximum was 69 days for the same sort with soaked pods. By reducing the drying period, the activity of microorganisms, fungus and also rising of alpha toxins were limited.

Optimal drying times for different sorts of vanilla pods were found under two drying methods. These average amounts for soaked process of drying were 35.5 days for sort I, 30 days for sort II, 25 days for sort III and 17.5 days for sort IV and the average amounts for non-soaked drying process were 60.5 days for sort I, 46 days for sort II and III and 11 days for sort IV.

In terms of energy consumption and drying time, it is clear that the soaked drying method is advantegous. Soaked drying is usually called the wet process and is used mainly in the former French colonies and Indonesia. Non-soaked drying is called a dry process and is used mainly in Mexico (Rakotoarisoa and Shapouri, 2001; Gassenmeier *et al*., 2008).

By this research, equations with high confidence intervals were found for vanilla drying. By these equations and graphs it is possible to predict the optimal drying period of any kind of vanilla pod sort in tropical regions like Tapanuli Utara in Indonesia. Such knowledge will lead to better utilization and processing of vanilla, higher yields, reducing of labor force and product loss.

Besides, this described drying process (soaked drying method) might be easily adapted to drying of any kind of agricultural products.

Results of this study may help farmers, engineers and researchers working on this topic. But, of course, enough scientific research must be done on various agricultural products to prove the drying method.

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Quantifying Farm Women Involvement in Different Paddy Cultivation Practices in Tamil Nadu

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Abstract

Women in rural India account for a significant share of wage labour in agriculture. Although their earnings contribute significantly to household incomes, many of the agricultural activities that women perform go unacknowledged as work, so that rural women are sometimes referred to as "invisible farmers". The nature and extent of their involvement in agriculture, no doubt, varies greatly depending on regions, ecological sub-zones, farming system, castes, classes and stages in family cycle. Technological change in agriculture, to the extent that it increases returns to labour and land, has a direct bearing on women earnings especially for women who have some control over income from land. Augmenting women's effective earning capabilities can also enhance their status and security in the family.

Thus, an attempt was made to examine the involvement of men and women in various farm operations in paddy cultivation using 8 row improved direct paddy seeder and manual transplanting. Data were collected from a representative sample of 60 growers using 8 row TNAU improved direct paddy seeder (locally called drum seeder) and 30 growers using manual transplanting of paddy in different villages of Pudukkottai and Tiruchirapally districts of Tamil Nadu during the year 2008-09. The participation of male and female labour was recorded for all the operations performed in the paddy cultivation. Women Involvement Index in farm operation (WII) was also calculated using following formula:

$$WII = [TN_w \times TT_w / (TN_m \times TT_m + TN_w \times TT_w)]$$

where

WII = Women Involvement Index in farm Operations,

TN_w = Total number of farm women involved in all operations

TN_m = Total number of men involved in all operations

TT_w = Total time spent by farm women in the operations, days/ha

TT_m = Total time spent by men in the operations, days/ha

The study revealed that the hand weeding, harvesting and threshing were the major operations performed predominantly by the women in cultivation of direct seeding of paddy; while transplanting, weeding, harvesting and threshing were the important operations of women involved in cultivation of transplanted paddy. Women also played a role in many other farm activities including application of manure, fertilizers and irrigation, but were excluded from activities which required operation of machinery in the operations like tillage, seeding by drum seeder, weeding by cono-weeder and harvesting by combine. Women Involvement Index in farm operations (WII) was found to be 0.62 that varied from 0.56 to 0.73 across the selected villages. The operations that showed involvement index of more than 0.60 were transplanting, weeding, harvesting and threshing. This indicated the monotony of farmwomen in these operations for paddy cultivation. Though crop establishment and weeding are traditionally women dominated jobs, the 8-row seeder and the cono-weeder were generally operated by male workers due to the higher efforts requirement. In view of this, it was necessary to develop/promote friendly equipment suitable for women so as to take care of their job opportunities.

Introduction

Women in rural India account for a significant share of wage labour in agriculture, typically providing crucial support for poor farm households. Although their earnings contribute significantly to household incomes, many of the agricultural activities that women perform go unacknowledged as work, so that rural women are sometimes referred to as "invisible farmers". Augmenting women's effective earning capabilities can also enhance their status and security in the family. The nature and extent of their involvement in agriculture, no doubt, varies greatly depending on regions, ecological sub-zones, farming system, castes, classes and stages in the family cycle. It is increasingly being recognized that if agricultural output and productivity is to be raised on a substantial basis, that new technologies have to address the specific requirements and skills of women in the farm sector. Yet, there are few studies that quantify the role of women in agricultural work. It is in this context that the present study was undertaken. In particular, it examines the participation of men and women in various farm operations in different paddy cultivation practices in Tamil Nadu.

Data and Methodology

An attempt has been made to examine the involvement of men and women in various farm operations in paddy cultivation using 8 row improved direct paddy seeder and manual transplanting. Data were collected from a representative sample of 60 growers using 8 rows TNAU improved direct paddy seeder (locally called drum seeder) and 30 growers using manual transplanting of paddy in different villages of Pudukkottai and Truchirapally districts of Tamil Nadu during the year 2008-09. The participation of male and female labour was recorded for all the operations performed in the paddy cultivation. Women Involvement Index in farm operation (WII) was also calculated using following formula:

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TT_m = Total time spent by men in the operations, days/ha

Results and Discussion

Cost and Returns in Traditional and Direct Seeding Methods

The profitability of direct seeding method of paddy cultivation in the study area has been analysed by computing per hectare cost and returns and comparing them with those of the traditional method. The pattern of inputs used in both the methods of paddy cultivation for sample farmers is presented in **Table 1**. The quantities of seed, nitrogen, phosphorus, potash, plant protection chemicals, human labour and bullock labour used in traditional method of paddy cultivation were 70 kg, 92 kg, 74 kg, 84 kg, 1,934 ml, 167.18 man-days and 18 pair-days respectively, which were larger than the quantities of 20 kg, 81 kg, 62 kg, 72 kg, 1,022 ml, 127.04 man-days and 9 pair-days correspondingly, in direct seeding method. Tractor and electric motor use were also high in the traditional method as compared to the direct seeding method. It may be noted that direct seeding method by the drum seeder equipment involved careful sowing of pre-germinated seed and 1 to 2 inter-cultivation/weeding by the Cono Weeder. The per hectare cost of cultivation in traditional method (Rs. 40,960) was more when compared to that in direct seeding method (Rs. 30,102). The share of human labour cost in total cost was 40.77 percent in the traditional method and 42.18 percent in the direct seeding method. The contribution of machine labour (tractor plus electric motor) cost in total cost was 10.35 percent in the traditional method and 9.42 percent in the direct seeding method. Fertilisers were the next important item of expenditure in both the methods of paddy cultivation which worked out to be 7.70 percent and 8.97 percent of total cost, respectively, in traditional and direct seeding methods. The amount spent on farmyard manure (Rs. 859) was higher in the case of the traditional method as compared to that in the direct seeding method (Rs. 804). There was a glaring difference in the costs incurred on seeds between the two methods, mainly due to smaller quantity of seeds used in the direct seeding method. The considerable difference in plant protection chemicals between the traditional method (Rs. 2,667) and the direct seeding method (Rs. 1,170) was due to the fact that the incidence of pests in the study area was less in the direct seeding method.

The majority of paddy growers of the direct seeding method used certified seed from the market and those seeds had resistance from pests. The rental value of land was also a major item of expenditure contributing to the fixed cost (14.65 percent and 19.93 percent, respectively, in traditional and direct seeding methods). The share of variable cost in the total cost was 83.13 percent (Rs. 34,048) in the traditional method and 77.06 percent (Rs. 22,198) in the direct seeding method. As such, variable cost was found to be less by about Rs. 10,850 in the direct seeding method, when compared to the traditional method.

The yield realised in the traditional method was 5.6 tonnes per hectare, while it was 6.8 tonnes per ha in the direct seeding method. The yield difference was mainly because of more productive tillers per m^2 in the direct seeding method. The growth of more productive tillers in direct seeding method was due to the interculture/weeding by the Cono weeder that provided sufficient aeration to the root zone of the paddy plants. The net returns per hectare realised was much higher in the direct seeding method (Rs. 41, 298) as compared to the traditional method (Rs. 17,839). This was mainly due to higher gross returns (Rs. 71,400) in the direct seeding method, where paddy yield harvested was more. The returns per rupee spent in the traditional method were Rs. 1.44 against Rs. 2.37 in the direct seeding method. These findings clearly indicated that direct seeding method was a better yielding technology. The difference in the use of most of the inputs between the two methods were evident. Direct seeding technology demanded less input as compared to the traditional method of paddy cultivation. Therefore, promotion of direct seeding technology could result in substantial yield gain and efficient use of scarce resources.

Table 1 Per hectare input and output in traditional and direct seeding methods

Particulars	Units	Traditional method		Direct seeding method	
		Quantity	Value	Quantity	Value
A: Variable cost					
Seed	Kg	70	1,540 (3.76)	20	440 (1.46)
Fertilizer					
Nitrogen	Kg	92.00	1,007 (2.45)	81.00	886 (2.94)
Phosphorus	Kg	74.00	1,477 (3.60)	62.00	1,237 (4.11)
Potash	Kg	84.00	672 (1.64)	72.00	576 (1.91)
Farmyard Manure	Tonne	3.45	859 (2.09)	3.23	804 (2.67)
Agro-chemicals	ml	1,934.00	2,667 (6.51)	1,022.00	1,170 (3.89)
Human labour	Man-days	167.18	16,700 (40.77)	127.04	12,700 (42.18)
Bullock labour	Pair-days	18.00	3,600 (8.80)	9.00	1,800 (5.98)
Machine labour					
Tractor	hour	8.37	2,929 (7.15)	5.20	1,820 (6.05)
Electric motor	hour	88.00	1,312 (3.20)	68.00	1,016 (3.37)
Interest on working capital	Rs.		1,171 (2.85)		625 (2.08)
Iirrigation charges	Rs.		113 (0.28)		123 (0.41)
Total variable cost	Rs.		34,048 (83.13)		23,198 (77.06)
B: Fixed cost					
Land revenue	Rs.		22 (0.05)		23 (0.08)
Rental value of land	Rs.		6,000 (14.65)		6,000 (19.93)
Depreciation	Rs.		345 (0.84)		383 (1.27)
Interest on FC	Rs.		544 (1.32)		498 (1.65)
Total fixed cost	Rs.		6,912 (16.87)		6,904 (22.93)
C: Total cost	Rs.		40,960 (100)		30,102 (100)
Main product	tonnes	5.6		6.8	
By product	tonnes	4.43		5.1	
D: Gross return	Rs.		58,800		71,400
E: Net returns	Rs.		17,839		41,298
F: B-C ratio			1.44		2.37

Labour Use Patterns in Paddy Cultivation

Paddy is the most important staple food crop grown through out the year in the study area. The timely availability of labour to complete the crucial operations is important to realise the full yield potential of the crop. The labour utilization pattern along with this disaggregation by gender for both the cultivation practices of paddy have been shown in detail in **Table 2**. Gender-specificity to crop operations, and a skewed pattern of demand for per unit total requirement for a particular operation, is the salient features of labour use in the crop. On an average, paddy production requires 127.04 days of labour per ha under the direct seeding cultivation practices, of which women provide 62.90 percent of the total labour. Similarly, paddy cultivation by manual transplanting method requires 167.18 man days/ha, of which the women contribution is 62.14 percent. The study further revealed that weeding/interculture, harvesting and threshing were women dominating operations for paddy cultivation under the direct seeding method while transplanting, weeding/interculture, harvesting and threshing were the operations of transplanted paddy cultivation in which women contribution was very high as compared to their male counterpart.

Harvesting and threshing itself involves several activities, including harvesting, making of bundles of harvested paddy, transportation from field to threshing floor, threshing, cleaning, and so on. For many of these, women tend to be involved in relatively greater numbers. Weeding/interculture was the other most time consuming operation in which women involvement was more than 80 percent in both the cultivation practices of paddy cultivation. Weeding/interculture is a critical operation, and its timely completion translates directly into higher yields particularly in case of the direct seeding method. Weeding/interculture by the Cono Weeder is meticulous work and mainly done by the male labour due to higher force requirement. After Cono weeding, hand weeding was completed by the women, believed to be more in the domain of what women do best.

Women Involvement Index

Average Women Involvement Index (WII) in farm operations was 0.62 that varied from 0.56 to 0.73 across the selected villages. The operations that showed involvement index of more than 0.60 were transplanting, weeding, harvesting and threshing and indicate the monotony of farmwomen in these operations for paddy cultivation.

Gender Disparities in Wages

Wage differentials between male and female labourers are pervasive, far greater than the differentials across the villages. Female wage rates are lower than those of males for similar type of work. Wage rates are determined on several considerations such as—type of work, availability of labour, basis of payment, i. e. piece rate or daily wage, and the prevailing wage rate in the locality. The wage rates paid to casually hired labourers in villages of the study area are indicated in **Table 3**. Wage rates vary from Rs. 100 to Rs. 120 per day for men and Rs. 70 to Rs. 80 for women for transplanting of paddy in Pudikkottai districts while wages for male and female are lower in Tiruchirapally district for the same operation. In each case, women are paid less than men.

There are indications that wage differential may well narrow with time. This is because contract labour system is becoming increasingly popular in the study area, even though, as yet, three-fourths of the hired labour is contracted on daily wages. The increased popularity of contract labour system may be attributed to the perception that it enhances bargaining power of workers. The employer prefers it, as it appears to improve labour productivity and lower monitoring costs. Contract labour system is being undertaken in various forms. All women teams are used for transplanting and weeding; all men teams for intra-field bund construction, tillage, making water channels, etc. in the case of irrigated paddy, and mixed team for operations such as harvesting, threshing and winnowing.

It is interesting to highlight that equivalence units between male and female labour are not employed in joint piece rate contracts. The per unit wage is the same for men and women, and wages are distributed to the members of the team in proportion to the quantum of work done. Indeed, if the contract labour system continues to increase in sig-

Table 2 Labour utilisation pattern in different cultivation practices of paddy by gender (Labour days/ha)

Farm operations	TNAU improved direct paddy seeder (8 row)			Manual transplanting		
	Female	Male	Total	Female	Male	Total
Tillage	-	3.28 (100)	3.28 (100)	-	3.65 (100)	3.65 (100)
Nursery raising	-	-	-	2.12 (25.03)	6.35 (74.97)	8.47 (100)
Sowing/ transplanting	0.38 (15.51)	2.07 (84.49)	2.45 (100)	31.44 (81.32)	7.22 (18.68)	38.66 (100)
Manure application	-	6.18 (100)	6.18 (100)	-	6.05 (100)	6.05 (100)
Fertilizers application	-	2.32 (100)	2.32 (100)	-	2.55 (100)	2.55 (100)
Weeding/ interculture	58.20 (84.04)	11.05 (15.96)	69.25 (100)	45.70 (82.91)	9.42 (17.09)	55.12 (100)
Irrigation application	3.35 (39.41)	5.15 (60.59)	8.50 (100)	3.11 (27.79)	8.08 (72.21)	11.19 (100)
Plant protection	-	5.05 (100)	5.05 (100)	-	5.16 (100)	5.16 (100)
Harvesting &threshing	17.37 (57.88)	12.64 (42.12)	30.01 (100)	21.01 (57.83)	15.32 (42.17)	36.33 (100)
Total	79.92 (62.90)	48.12 (37.88)	127.04 (100)	103.38 (62.14)	63.80 (37.86)	167.18 (100)

(Figures in parentheses are percent to total labour used in respective operation)

Table 3 Wage rates of male and female agricultural workers for different operations

Farm operations	Daily wage rates (Rs./day) in villages of Pudukkottai district		Daily wage rates (Rs./day) in villages of Tiruchirapally district	
	Male	Female	Male	Female
Transplanting	100-120	70-80	80-100	55-70
Weeding	80-100	60-80	60-80	50-70
Harvesting	120-150	100-120	100-120	80-100

nificance, it is likely that there will be a further narrowing of gender-based wage differentials.

Conclusions and Recommendations

This paper demonstrated the visible nature of women's work in the study area of Tamil Nadu. There was a great deal of specificity to labour use in paddy crop production. Women played a greater role in the production of paddy in different production technology. Transplanting, hand weeding, harvesting and threshing were the major operations performed predominantly by the women in paddy cultivation under traditional and direct seeding methods. Women, also, played a role in many other farm operations like nursery raising, sowing, and application of irrigation. Average Women Involvement Index (WII) in farm operations was found to be 0.62 that varied from 0.56 to 0.73 across the selected villages. The operations that showed involvement index of more than 0.60 were transplanting, weeding, harvesting and threshing. This indicated the monotony of farmwomen in these operations for paddy cultivation. Though crop establishment and weeding are traditionally women dominated jobs, the 8-row seeder and the cono-weeder were generally operated by male workers due to their high effort requirement. In view of this, it is necessary to develop/promote suitable women friendly equipment so as to take care of their job opportunities. Gender disparities in wages are quite marked in the study area. Female wage rates are lower than those of males for similar type of work. The study further revealed that the difference in the use of most of the inputs between the two methods are evident. Direct seeding technology demands less input as compared to the traditional method of paddy cultivation. Therefore, promotion of direct seeding technology could result in substantial yield gain and efficient use of scarce resources.

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ABSTRACTS

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

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Mechanical Properties viz. Tenacity and Extension at Break of Ramie (Boehmeria nivea L.) Fibres Extracted from Ramie Crop Grown in Konkan Region of Maharashtra (India): **S. K. Jain**, Associate Professor, Department of Farm Structures, College of Agril. Engg. & Tech., Dapoli, Dist. Ratnagiri, INDIA; **P. G. Patil**, Professor & Head, same; **P. P. Chavan**, Agril. Engineer, same; **V. T. Badhe,** Associate Dean, same.

Ramie (Boehmeria nivea L.), one of the oldest fibres native to Eastern Asia, is a herbaceous perennial crop. The ramie crop was grown in Konkan region of Maharashtra and fibres were extracted from the bark and stem using bast fibre extractor and degummed by 1 % NaOH solution. To study the effect of nitrogen, phosphorus and potassium doses on the quality of ramie fibres under Konkan conditions, the crop (variety R: 1412) was grown at experimental farm of Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli under eight different fertilizer dosages viz. control (no fertilizer), N_{30}, N_{30} P_{15}, N_{30} K_{15}, N_{30} P_{15} K_{15}, N_{30} (100 % through Farm Yard Manure i.e. FYM) P_{15} K_{15}, N_{30} (50 % through FYM) P_{15} K_{15}, N_{30} (25 % through FYM) P_{15} K_{15} kg/ha. The fibers were extracted by using Bast Fibre Extractor. Study revealed that tenacity was highest for fibres which were extracted from the crop grown under the fertilizer treatment of N_{30} P_{15} K_{15} kg /ha where 25 % of the nitrogen was supplied through FYM and found to be 19.1 g/tex. Keeping phosphorus and potash same and when nitrogen was applied at 100 %, 50 % and 25 % through FYM, the tenacity found to be 14.3, 15.4, and 19.1 g/tex respectively. Therefore, it is concluded that nitrogen through synthetic fertilizers played positive role. The minimum tenacity of 8.2 g/tex was observed for the ramie fibres, which were extracted from the crop that was grown as control i.e. no application of fertilizers. Fibre tenacity of 11.6, 13.0 and 14.8 g/tex were observed for fertilizer dosage of N_{30}, N_{30} P_{15} and N_{30} K_{15} kg/ha respectively suggesting that both phosphorus and potassium have positive effect on the tenacity and potassium has a greater effect than phosphorus. Further the maximum and minimum extension at break of 3.72 % and 2.4 % was observed for the ramie fibres, which was extracted from the ramie crop grown under fertilizer treatment of N_{30} P_{15} K_{15} kg/ha and N_{30} P_{15} K_{15} kg/ha (50 % N was applied through FYM) respectively. Statistical analysis showed that extension at break (%) of ramie fibres for crop grown under control does not differ significantly from all other fertilizer treatments.

Solar Energy Utilisation for Providing and Maintaining Optimal Microclimatic Conditions of Greenhouse Cucumber

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Abstract

The main goal of the present study was to evaluate the effects of two different glazing materials (fiberglass and polyethylene) on microclimatic conditions of gable-even-span single greenhouses at night during the winter season of 2007-2008. A complete solar heating system was utilized for heating the cucumber greenhouses located in the eastern area of the coastal delta, Egypt. Temperatures of inside and outside air, water in the storage tank, pipe surface of heat exchanger, floor surface (concrete), and air relative humidity were measured and recorded on a data-logger to analyze their correlation with the cucumber crop yield response. A mathematical model was developed to simulate microclimatic conditions for the cucumber greenhouse. The data showed that the daily average solar energy available was 13.345 kWh of which 7.138 kWh was stored in the storage tank of each solar energy system. There were daily variations during the experimental period that depended upon the water temperature in the storage tank at the beginning of each day, the ambient air temperature, the rate of heat energy consumed at night to provide and maintain the air temperature within the greenhouses at the desired level, and the growth stage of the cucumber crop. The daily average heat energy consumed at night for heating the two greenhouses was 10.070 and 12.391 kWh and the polyethylene greenhouse consumed heat energy greater than the fiberglass greenhouse by 23.05 %. The heat energy consumed resulted in an increase of the inside air temperatures above the outside (12.6 ºC) by 4.5 ºC and 3.4 ºC for fiberglass and polyethylene greenhouses, respectively. Under these conditions, the fiberglass and polyethylene covers provided, respectively, a heating effect of 4.5 ºC and 3.4 ºC. The nightly average air relative humidity inside and outside the two greenhouses was 56.5 %, 60.8 % and 54.4 %, respectively. The proportions of heat energy provided by utilizing the solar energy system for the two greenhouses, respectively, were 65.95 % and 55.68 %. Due to the optimal level of microclimatic conditions of the two greenhouses, they produced a fresh cucumber yield of 6.825 and 5.245 kg/m^2, respectively. Thus, the fiberglass greenhouse increased the fresh yield of cucumbers by 30.12 % as compared with the polyethylene greenhouse.

Introduction

The optimization of air temperature in greenhouses can have a significant impact on the plant growth, development, and productivity. In order to implement optimal inside conditions, it is necessary to heat the greenhouses, particularly at night during the winter. Present fuel prices and projected increased prices have emphasized the need to reduce energy consumption for space heating. To overcome these problems it is imperative to utilize alternative heating technologies, with low cost, and efficient and dependable operation, such as the use of renewable energy.

Worldwide research and development in the field of renewable energy resources and systems has been carried out during the last two decades. Energy conversion systems based on renewable energy technologies appeared to be cost effective compared with the projected high cost of oil. Furthermore, renewable energy systems can have a beneficial impact on the environmental, economic, and political issues of the world. At the end of 2001 the total installed capacity of renewable energy systems was equivalent to 9 % of the total electricity generation (Kalogirou, 2004). In this research emphasis is given to solar thermal systems. Solar energy is non-polluting and offers significant protection of the environment. Therefore, solar thermal systems should be employed whenever possible in order to achieve a sustainable future. The solar energy collected by solar thermal systems is carried from the circulating fluid either directly to the hot water or space conditioning equipment or to a thermal energy storage tank from which it can be drawn for use at night and/or cloudy days (Sayigh, 2001 ; Kalogirou, 2003).

Heating of a greenhouse is an essential requirement for proper growth and development of winter growing crops (Tiwari, 2003). Thermal heating of greenhouses has been studied by several researchers in employing different passive methods as well as active modes (Hussaini and Suen, 1998 ; Ismail and Goncalves, 1999 ; Bargach *et al*, 2000 ; Kurpaska and Slipek, 2000 ; Jain and Tiwari, 2003; and Abdellatif *et al*., 2007). Among the active heating modes, a solar thermal system is one of the most practical and appropriate means for reducing the operating costs in a greenhouse. If the heating pipes are galvanized or painted with aluminized paint, heat delivery rates will be approximately 15 % less than from black pipe (ANSI/ASAE, 2003).

The wide distribution of protected cultivation in Europe and other Mediterranean countries has increased the production and marketing of a large variety of greenhouse covering materials. The covering material is a basic factor influencing the energy consumption, the yield and the general economics of the greenhouse. A better knowledge of the properties and relative performance of different materials has great importance for both the scientists and the growers. Of particular interest is the durability of these materials and their capacity for influencing the microclimate inside the greenhouse. The characteristics of the greenhouse covering materials depends strongly on their mechanical and physical properties (Papadakis *et al*., 2000).

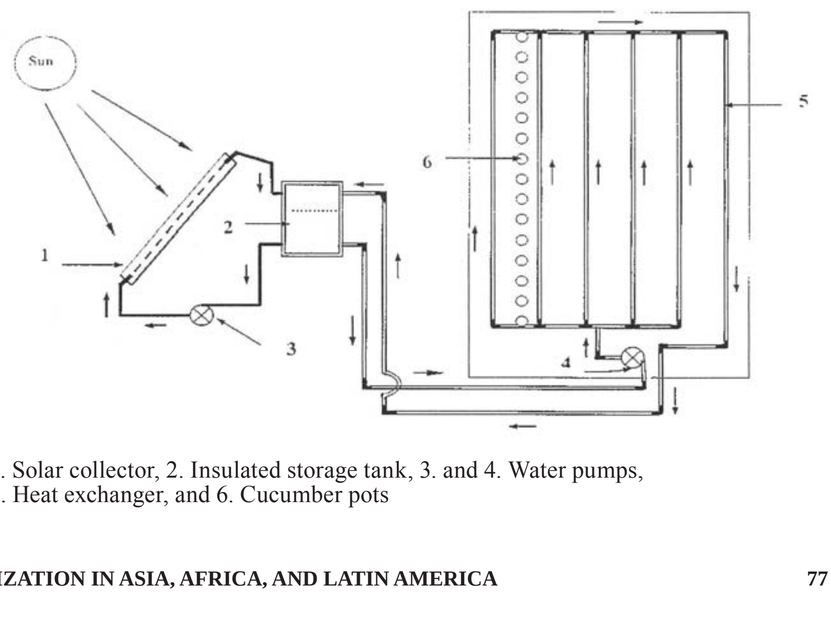
The main objective of this research work was to investigate the possibility of utilizing a solar thermal system for heating two cucumber greenhouses during the winter of 2007-2008. The effect of different glazing materials (fiberglass and polyethylene) on heat energy loss at night was investigated. A mathematical thermal model was developed to simulate the microclimate on and around leaf surfaces for greenhouse cucumbers.

Materials and Methods

Solar Heating System

Two identical solar thermal systems (solar collector, storage tank, and heat distributing system) were employed for heating two cucumber greenhouses located at the University of Mansoura (Latitude and longitude are 31.045 ºN and 31.37 ºE, respectively, and 19.05 m above the sea level) in the eastern area of the coastal delta, Egypt. The solar collectors were mounted individually on movable frames which were adjusted manually to change the orientation and tilt angle once each hour so that, at that time, the angle of incidence of the surface of the solar panel and the sun's rays was set at zero. The operating fluid (water) was pumped through the solar panel. After passing through the solar panel it was stored in a 400 liter insulated storage tank as shown in **Fig. 1**. Each storage tank was equipped with a supplemental electric heater (1,500 Watt). The supplemental heaters were used when the stored solar energy was insufficient to provide the requirements of the heat energy supply. The water pumps were switched ON and OFF manually on sunny days from November 1, 2007 until May 11, 2008. The flow rate of the operating fluid (18 l/min.) was adjusted and controlled every day using a control valve and a measuring cylinder with stop clock. To provide and maintain positive temperature of 16-18 ºC at night during cold winter months, such as recommended for cucumber

Fig. 1 Schematic diagram of the solar energy system arrangement



1. Solar collector, 2. Insulated storage tank, 3. and 4. Water pumps, 5. Heat exchanger, and 6. Cucumber pots

crop (Aldrich and Bartok, 1990 and Nelson, 1996), each greenhouse was equipped with two heat exchangers using a parallel flow system in order to utilize the stored energy from the storage tank for heating the inside air of the two greenhouses as shown in **Fig. 1**. The heat exchangers were placed at a horizontal distance of about 75 cm between each two pipes to provide adequate area of heat transfer. They were located on an iron stand above the floor surface by 35 cm (the coldest zone inside the greenhouse). The solar heated water from the insulated storage tank was pumped through the heat exchanger. It was controlled by an ON-OFF controller to initiate heating at 16 ºC and interrupt it at 18 ºC (environmental control board with differential thermostat).

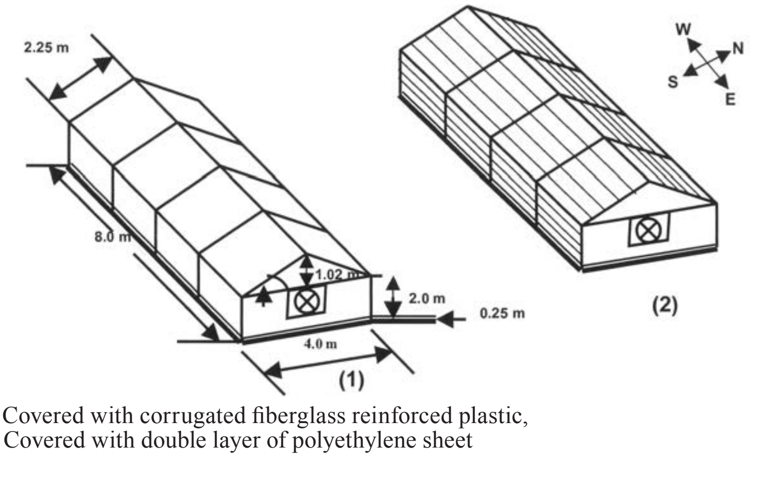
Gable-Even-Span Single Greenhouses

The experiment was carried out during 2007-2008 winter season in two similar gable-even-span single greenhouses, E-W orientated, and located at the University of Mansoura. The geometric characteristics of each greenhouse are as follows: eave height, 3.25 m, height of each side wall, 2 m, rafter angle, 27º, width, 4 m, length, 8 m, floor surface area, 32 m^2, and volume, 87.7 m^3. The two greenhouses (G1 and G2) were covered using two different glazing materials of 800 µm thick corrugated fiberglass reinforced plastic (FRP) and a double layer of polyethylene sheet (PE) of 150 µm (as an inner layer) and 200 µm (as an outer layer), respectively. The greenhouse facility used in was covered with the ratio of cover surface area to the total greenhouse surface area of 2.685. To increase and maintain the durability of the structural frame and polyethylene cover, twenty tensile galvanized wires (2 mm diameter) were tied and fixed throughout the rafters and vertical bars in each side of the plastic greenhouse as shown in **Fig. 2**.

Ventilation and Cooling Systems

Ambient air was forced through 1.80 m^2 face area of 10 cm thick cooling pads situated on the middle of the western wall (side toward the prevailing winds). These corrugated cellulose pads permitted 75 m^3/min/m^2 air flow rate. After crossing the pads, air traveled 8 m before being extracted by one fan located on the opposite western side wall. Each extracting fan generated a flow rate of about 8,000 m^3/h under 2.5 mm static pressure. The cooling process by ventilation was mostly used when the air temperature outside the greenhouse was lower than 20 ºC. However, when the ambient air temperature outside the greenhouse was higher than 20 ºC, the evaporative cooling system was operated.

Fig. 2 Schematic diagram of gable-even-span greenhouses



1. Covered with corrugated fiberglass reinforced plastic,
2. Covered with double layer of polyethylene sheet

Cultivation System

Pots system was used for protecting the cucumber crop. Each greenhouse was equipped with 60 plastic pots 30 cm high and 28 cm diameter, which were arranged in five rows (each row having twelve pots). These pots contained a mixture of three different types of soil; clay soil (pasteurized at 105 ºC for 20 minutes), pure yellow sand, and Irish peat moss with ratio of 1:1:1. In addition to this mixture, one-half kilogram of compost as an organic substance was added to each pot's mixture. One hundred and thirty cucumber seed (Beit Alfa GH, George Spirou Co., Greece) were directly planted in the pots on October 20, 2007. After ten days, the cucumber plants started to rise up in the pots with a germination ratio of 95.5 %.

Watering System

A drip irrigation system was used for watering the plastic pots of cucumber plants. A 200 liter scaled plastic water supply tank (96 cm high, and 55 cm diameter) was located inside the greenhouse 1 m above the ground surface in order to provide adequate hydrostatic pressure for maximum use rate of water. Twelve drippers (long-bath GR 4 liter/hr discharge) were uniformly and alternative distributed with 48 cm dripper spacing throughout each row of plants inside the greenhouses.

Measurements and Data Acquisition Unit

The solar radiation, air temperature, air relative humidity, and wind speed and direction outside the greenhouses were measured and recorded using a meteorological station (WatchDog model 550) installed just above the greenhouses. A disk solarimeter was fixed and installed on the top frame of solar water heater in order to measure the solar radiation flux incident on a tilted surface. Two disk solarimeters were located just above the canopy of cucumber (2.25 m) inside the two greenhouses. These sensors were also connected to the same data-logger system to display and record the data throughout the experimental work. Another meteorological station (WatchDog model 550) for internal microclimate variables within the centre of the greenhouse 1 was installed at an altitude of 1.8 m above the ground surface. The internal microclimate variables included global solar radiation above the canopy of cucumber plants, dry-bulb air temperatures, air relative humidity, pipe temperature of heat distributing system, and floor surface temperature. A 12 channel data-logger (Digi-Sense Scanning Thermometer Type) was also used for collecting and recording reading from the different sensors (thermocouples type K) located inside the greenhouse. Two thermocouples were used to measure the inlet and outlet water temperatures of each solar collector. The water temperature in the storage tanks was measured using two thermocouples, located at the centre of each tank. Three thermocouples were used to measure the interior air temperatures along and across the centerline of each greenhouse at a height of about 0.6 m, 1.2 m and 1.8 m above the floor. The temperatures of several leaves at different locations were measured using an infrared thermometer (Raytek, Raynger ST60). The recorded data were stored in the memory for output to a printer or to a computer for storage on disk. The time interval for data recording was 5 min with data acquisition every one minute for integrated measurements. The calibration of all sensors and the logger were completed successfully at the beginning of the experimental work.

Methods

Heating Load and Energy Balance at Night during Winter Season

Temperature of the crop leaves during heating operation should be higher than the dew-point temperature in order to prevent condensation and thus reduce the risk of fungal disease. The heat energy supplying to the greenhouse during the night can be determined according to the fact that adding heat energy must be at the rate at which it is lost. The steady-state energy balance can be computed using the following equations (Teitel *et al*., 1999 ; Zhang *et al*., 2002 ; Ozturk and Bascetincelink, 2003 and ANSI/ASAE, 2003):-

$$q_{supply} - q_{loss} + q_{gain} = 0 \quad (1)$$

$$q_{supply} = q_{loss} - q_{gain} \quad (2)$$

The heat energy supplying (q_{supply}) arises when there is a positive difference between heat losses (q_{loss}) and heat energy gains (q_{gain}). The rate of heat flow supplied from the heat distributing system can be calculated from the following **Eqn.**:

$$q_{supply} = q_{sup,st} + q_{sup,un} \quad (3)$$

In a steady-state heat transfer process, the temperatures of the pipes and the greenhouse air are constant with respect to time (dτ). The rate of heat supply ($q_{sup,st}$) from the heat distributing system to the greenhouse can, therefore, be computed from the following **Eqn.**:

$$q_{sup,st} = m\ C_{pw} (T_{in} - T_{out})\ d\tau \quad (4)$$

where, m and C_{pw}, respectively, represent the mass flow rate and specific heat of the water, T_{in} and T_{out} are the inlet and outlet temperatures of the water in the main supply and return pipes, respectively, and, dτ, is the time interval during which the water circulates. When non-steady-state conditions prevail, energy estimations also have to take into account thermal storage energy in the water and the pipe material. The heat energy supplied during the cooling-down of the heat distributing pipes when the water pump switched OFF can also be determined. In that circumstance, the energy supplied ($q_{sup,un}$) for heating the greenhouse can be calculated from the following equation:

$$q_{sup,un} = (M_w C_{pw} + M_p C_{pp}) (T_{av} - T_e)\ d\tau \quad (5)$$

where, M_p and C_{pp}, respectively, are the mass and specific heat of the heating pipes, and M_w is the mass of the water in the pipes. The temperature at the beginning of the cooling-down phase, T_{av}, is the average of the inlet and outlet temperatures of the water at the start of the cooling-down period *(i.e.,* $T_{av} = (T_{in} + T_{out}) / 2$*)*. At the end of the cooling-down phase of a heating cycle the temperature of the pipe and water is equal to T_e.

An illustrative, but highly simplified, derivation begins with the steady-state heat losses. The total heat losses from the inside to outside of the greenhouse can be computed from the following **Eqn.**:

$$q_{loss} = q_{cl} + q_{inf},\ Watt \quad (6)$$

where, q_{cl}, is the combination heat losses (by conduction, convection, and radiation) through the concrete blocks and the glazing materials of the greenhouse. It can be estimated from the following **Eqn.**:

$$q_{cl} = U\,A\,(T_{ai} - T_{ao}),\ Watt \quad (7)$$

where, U, is the overall heat transfer coefficient for each section of the greenhouse, A, surface area of each section, and T_{ai} and T_{ao} ,respectively, are the inside and outside air temperatures of the greenhouse. The heat losses due to air infiltration through the structure (q_{inf}) from outside (cold air) to inside of the greenhouse (warm air) can be computed by considering that the total exchange is the sum of sensible and latent heat energy exchanges.

$$q_{inf} = m_a [C_{pa} (T_{ai} - T_{ao}) + h_{fg} (W_{ai} - W_{ao})],\ Watt \quad (8)$$

where, m_a and C_{pa}, respectively, are the mass flow rate of cold air and specific heat of cold air, h_{fg} is the latent heat of vaporization of water, W_{ai} and W_{ao} are the inside and outside humidity ratios of the greenhouse, respectively.

The total rate of heat energy transferred (by natural convection, $q_{conv.}$ and radiation, $q_{rad.}$) from the concrete floor surface area (q_{gain}) and gained by the inside air can be computed from the following **Eqn.**:

$$q_{gain} = q_{conv.} + q_{rad.}, Watt \quad (9)$$

The convection heat transfer from the bare floor surface to the inside air of the greenhouse can be estimated from the following formula:

$$q_{conv.} = h_f A_f (T_f - T_{ai}), Watt \quad (10)$$

where, h_f, is the convective heat transfer coefficient between floor surface and internal air, A_f, and T_f, respectively, are the bare floor surface area, and the floor surface temperature. The radiative heat transfer from the bare floor surface to the interior air of the greenhouse can be calculated from the following **Eqn.**:

$$Q_{rad.} = \varepsilon_f A_f \sigma (T_f^4 - T_{ai}^4), Watt. \quad (11)$$

where, ε_f, is the emissivity factor of the floor surface, and σ, is the Stefan-Boltzmann constant.

Data were measured and stored in microcomputer files and statistically analyzed using an Excel program. Once a computer model was tested and found to be accurate, it .could be used to predict the results which could otherwise be obtained with extensive and costly experimentation.

Results and Discussion

The two solar energy systems operated satisfactorily for six months without any malfunction. For the duration of the experimental period, there were 928 hours of bright sunshine of which 812 hours (87.5 %) were recorded and used in the thermal performance analysis and applications. Because the two solar collectors used the same orientation and tilt angle under the same climatic conditions, there was no difference in the thermal performance. Under clear skies, the solar energy available, absorbed solar energy, useful heat gain to storage, overall thermal efficiency, and solar energy stored in the storage tank increased gradually with solar time from sunrise until they reached maximum values at noon. They, then, declined until they reached minimum values just before sunset. The thermal performance analysis of the solar heating system was mainly determined by its overall thermal efficiency in converting solar energy into stored heat energy.

Effect of Glazing Material on Microclimatic Conditions:

The results presented in this section concerned three consecutive 6-day periods of measurement obtained during each month. Microclimatic conditions of the two greenhouses were mainly affected by many variables. Some were related to the structural frame of the greenhouse and its orientation, and others were related to the climatic circumstances, namely: intensity of solar radiation during daylight, outside air temperatures throughout the day, air relative humidity, and wind speed.

Air Temperature and Air Relative Humidity:

The effectiveness of glazing materials in energy conservation was investigated in particular for the coldest days during the experimental period. The air temperatures inside the two greenhouses (G1 and G2) were compared with the outside air temperature as an important measure of the effectiveness of the covering materials. The fluctuations of air temperature surrounding the crops played an important role for their growth rate, development, and productivity. Fluctuation in air temperature, caused by the ON-OFF control board were observed inside the two greenhouses. A temperature gradient developed along the centerline of each greenhouse and its value varied with time during each heating cycle.

The air temperature inside the two greenhouses (G1 and G2) at night varied between 15.3 ºC and 19.2 ºC, and between 13.5 ºC and 18.9 ºC, respectively, whereas, the outside air temperature ranged from 9.0 ºC to 17.4 ºC. The highest air temperatures inside the two greenhouses (18.9 ºC and 17.0 ºC, respectively) during month of January (coldest month) were recorded at 19:00 h, just two hours after sunset. The air temperature (18.9 ºC) in the fiberglass greenhouse was from the heat energy stored during the daylight, therefore, the heating process was not used over this hour, whereas, the air temperature (17.0 ºC) in the polyethylene greenhouse was obtained from the first heating cycle. The lowest air temperatures inside the two greenhouses (15.3 ºC and 13.7 ºC, respectively) were also recorded during January month at 6:00 h just prior to sunrise. The lowest air temperatures inside the two greenhouses occurred due to three reasons. First, the majority of heat energy stored in the storage tank during daylight (from solar energy system) and supplementary heat energy added (from auxiliary electric heater) were consumed during the heating cycles at night. Secondly, the air temperature difference between the set point and the outside was 8.0 ºC. Consequently, the greatest amount of heat energy was lost at that time. Thirdly, the fiberglass cover was able to keep the air temperature inside the greenhouse greater than that of the polyethylene cover. Under these circumstances, the fiberglass and the polyethylene cover provided a heating effect of 6.3 ºC and 4.5 ºC, respectively. The fiberglass cover provided a heating effect during January greater than the polyethylene cover by 40 %. The nightly average air temperature differences between the inside and outside of the two greenhouses varied from one month to another and, during the experimental period, according to the total heat lost and the heat energy supplied at night. The data revealed that, the heating effect by the fiberglass cover during the experimental period, on average, was 4.5 ºC, meanwhile, the polyethylene cover provided a heating effect, on the average, of 3.4 ºC. Under these conditions the fiberglass cover provided a heating effect greater than the polyethylene cover by 32.35 %.

The cyclic changes in air temperature within the two greenhouses during the air heating process of six successive nights in January (heat distributing system switched ON) are plotted as a function of time in **Fig. 3**. During the first heating cycle, the heating system inside the polyethylene greenhouse was switched ON 40 minutes prior to that system in the fiberglass greenhouse as observed in **Fig. 3**. At the peak of the heating cycle in the fiberglass greenhouse, the warm air continued to rise until reached 18.2 ºC, similarly to that observation with the polyethylene greenhouse. When the circulation of the hot water was stopped, the temperature of the pipes decreased and warm air continued to rise, due to thermal buoyancy effects. During the heating cycle in the fiberglass greenhouse, the lower region (0.6 m above the floor surface) appeared to be warmer by 1.2 ºC than the upper region (1.8 m), identical to the observation with the polyethylene greenhouse. However, at the end of the cooling-down period, this trend was reversed and lower region became colder than the upper region by about 0.8 ºC. This was apparently because of the fast upward flow of hot air due to thermal buoyancy slowdown immediately following the switch OFF in each heating cycle. The number of heating cycles per unit time was greater with the polyethylene greenhouse than with fiberglass greenhouse because of the large heat losses from the polyethylene cover as shown in **Fig. 3**.

The variation of air relative humidity as a function of time within the two greenhouses during the experimental period is plotted in **Fig. 4**. The air relative humidity inside the fiberglass and polyethylene greenhouses, respectively, ranged from 46.6 to 62.4 % and from 51.8 to 70.8 %, whereas, the outside air relative humidity was in the range of 31.9 to 69.8 %. The nightly average air relative humidity within the two greenhouses (G1 and G2) during the experimental period, respectively, was 56.5 % and 60.8 %. However, the nightly average outside air relative humidity was 54.4 %. Cyclic changes were, also, observed in the air relative humidity, and the humidity ratio which were measured in the fiberglass greenhouse and calculated from dry-bulb and wet-bulb temperatures in the polyethylene greenhouse. The cyclic variations in air relative humidity occurred at the peak of the heating cycle in the fiberglass greenhouse, similar to the observation with the polyethylene greenhouse. The air relative humidity inside the two greenhouses (G1 and G2) decreased by 5.2 % and 3.5 % at the peak of each heating cycle, whereas, at the end of the cooling down it was increased by 7.3 % and 8.1 %, respectively. The air relative humidity within the two greenhouses increased every night at the end of the heating period because the heat energy supplied during that time was insufficient to absorb more moisture from the inside air.

Most protected crops grow best within a fairly restricted range, typically 60 % to 80 % air relative humidity at night for many varieties (Ozturk and Bascetincelik, 2003). High air relative humidity is the main response for pathogenic organisms. Most pathogenic spores can not germinate at air relative humidity below 85 %. Low air relative humidity increases the evaporation demand on the plant to the extent that moisture stress can occur, even when there is an ample supply of water to the roots. Normal plant growth inside the greenhouse generally occurs at air relative humidity from 30 to 80 % (Hanan, 1998).

Since leaf temperature, air temperature and difference between them are very important parameters that affect growth rate, fresh yield and quality, these parameters in each greenhouse were measured during the six successive nights every month. The nightly averages of air, leaves, and dew-point temperatures inside the fiberglass greenhouse during the coldest month (January), respectively, were 16.6 ºC, 18.1 ºC, and 7.8 ºC. Whereas, these averages inside the polyethylene greenhouse were 15.0 ºC, 16.3 ºC, and 7.4 ºC, respectively.

Fig. 3 Cyclic changes in air temperature within the two greenhouses (G1 and G2) during the coldest month (January, 2008)

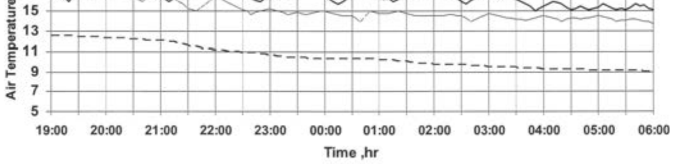
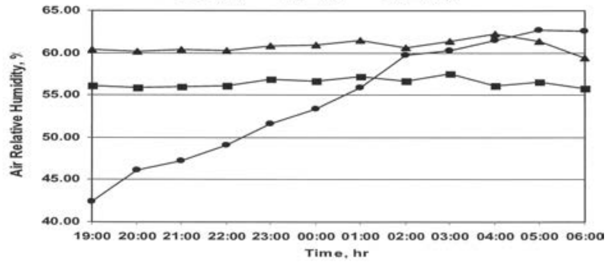


Fig. 4 Changes in air relative humidity within the two greenhouses (G1 and G2) as a function of time during the experimental period



Effect of Glazing Material on Heat Energy Supplied

The principal effect of greenhouses glazing material is to provide thermal resistance that reduces the overall rate of heat transfer to the surroundings. Most undesirable heat loss from a greenhouse occurs by longwave radiation, conduction and convection, and by infiltration. The total heat losses from the two greenhouses increased gradually with time from 19:00 h until they reached the maximum values at 6:00 h due to reduction in the outside air temperature. The hourly averages of heat energy loss from the fiberglass and the polyethylene greenhouses at night during the coldest month were 4.170 and 5.167 kWh, respectively. Consequently, the polyethylene cover increased the heat loss by 23.91 % as compared with the fiberglass cover. The main source of the concrete floor surface temperature was the solar energy absorbed during the daylight. An overnight decrease in the floor temperature was observed inside the two greenhouses due to conduction, convection and radiation heat transfers between the floor and the inside air. At night the heat energy gained from the floor was gradually decreased with time during the experimental period, as the surface temperature of the floor was reduced. Therefore, the greatest heat energy gained from the floor of the two greenhouses, respectively, was 0.7034 and 0.6919 kWh which was achieved at the beginning of each night during the experimental period, whereas, the lowest heat energy gained (0.3402 and 0.3325 kWh, respectively) occurred at the end of each night. The amount of heat energy supplied to keep the air temperature at a desired level was approximately equal to the heat energy lost from the two greenhouses. The nightly averages of heat energy supplied to the fiberglass and polyethylene greenhouses during the experimental period, respectively, were 28.884 and 35.714 kWh. Consequently, the polyethylene greenhouse required greater supplied heat energy than that supplied to the fiberglass greenhouse by 23.65 %. The greatest nightly average heat energy supplied to the two greenhouses (46.416 and 58.312 kWh, respectively) occurred in January as the largest heat energy losses occurred in that month.

The nightly average total heat energy consumed by solar energy and electrical energy (water pumps and auxiliary heaters) for the two greenhouses at night during the experimental period were 10.070 and 12.391 kWh/day, respectively. The polyethylene greenhouse consumed heat energy greater than that consumed with the fiberglass greenhouse by an average of 23.05 %. The heat energy consumed was strongly affected by the air temperature outside the greenhouses, solar collector surface area, and volume of water in the storage tank. As the ambient air temperature dropped below the set-point temperature inside the greenhouse, more heat energy was required to provide and maintain that temperature. The proportions of heat energy provided by utilizing the solar energy system for the two greenhouses, respectively, were 66.79 % and 56.09 %. The lowest amount of solar energy provided as a proportion of total energy consumed for the two greenhouses was 58.91 % and 50.71 %, respectively, which occurred in January as shown in **Fig. 5**. This proportion could be increased if the ratio between the solar collector surface area and floor surface area inside the greenhouse increased from 0.0625 to 0.1250, and the water flow rate passing through the solar collector was adjusted according to the incoming solar radiation and water temperature required for heat energy. Further research work is required to develop such control system.

Effect of Microclimatic Conditions on Cucumber Growth and Productivity:

The air temperatures within the two greenhouses were at or around the desired level, particularly in the fiberglass greenhouses and the cucumber plants grew well during the experimental period. Germination of cucumber seeds was accomplished after 6 days from the planting with a germination rate of

Fig. 5 Proportions of heat energy provided by utilising the solar energy system for the fiberglass and polyethylene greenhouses during the experimental period

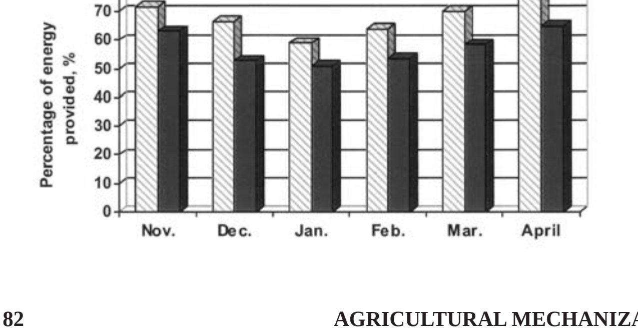
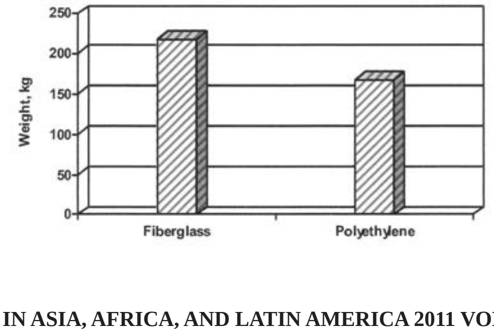


Fig. 6 Total fresh yield of cucumber crop for the two greenhouses during the experimental period



95.5 %. The weekly averages in the increase of leaves inside the fiberglass and polyethylene greenhouses, respectively, were 2.92 and 2.24 leaf/plant. This variation may be attributed to the reaction rates of various metabolic processes, absorption rate of nutrient elements, and release of water by the root system, which strongly affected by the microclimatic conditions, particularly the air temperature and relative humidity within the two greenhouses. As the number of leaves increased, the green surface area was increased, and the biochemical reactions increased making the photosynthesis process more active. This was in agreement with the data published by Aldrish and Bartok (1990) and Nelson (1996).

The weekly average stem length of cucumber plants for the two greenhouses was 15.70 and 12.04 cm/week, respectively. Consequently, the fiberglass greenhouse increased the growth rate of cucumber plants, on the average, by 30.40 % as compared with the polyethylene greenhouse. As the air temperature surrounding the plants was reduced lower than 15 ºC, slower growth rate, longer internodes, thinner xylem, and smaller rate of fruit set occurred. Due to the reasons discussed previously, the number of fruits being seated on the plants within the two greenhouses was, on the average, 28.1 and 21.6 fruits/plant, respectively. Therefore, the total fresh yield of the cucumber crop for the two greenhouses, respectively, was 218.4 and 167.8 kg. Thus, the fiberglass greenhouse was, on the average, 50.6 kg (30.2 %) more productive than the polyethylene greenhouse as shown in **Fig. 6**.

Conclusion

From the present study, the following conclusions were drawn:

1. The fluctuations of air temperature surrounding the crops play an important role for their growth rate, development, and productivity. Fluctuation changes in air temperature, caused by the on-off control board were observed inside the two greenhouses during the experimental period.
2. The lowest air temperatures recorded inside the fiberglass, polyethylene greenhouses and outside, respectively, were 15.3 ºC, 13.7 ºC, and 9.0 ºC, which occurred during January at 6:00 h just prior to sunrise. The fiberglass and polyethylene greenhouses substantially provided a heating effect of 6.3 ºC and 4.5 ºC, respectively, at that month. Thus, the fiberglass cover provided a heating effect greater than the polyethylene cover by 40 %.
3. The air temperature gradients varied slightly with time from one heating cycle to another during the first heating period. The variations with time during the rest of heating period were larger than that in the first time due to the water temperature in the storage tank decreasing, owing to the heat energy supplied to the greenhouse.
4. Cyclic changes were observed in the air relative humidity and the humidity ratio inside the two greenhouses. The air relative humidity inside the two greenhouses was decreased by 5.2 % and 3.5 % at the peak of each heating cycle. While, at the end of the cooling-down period it was increased by 7.3 % and 8.1 %, respectively. The nightly average air relative humidity inside and outside the two greenhouses during the experimental period, respectively, was 56.5 %, 60.8 % and 54.4 %.
5. The temperature differences between leaves and air were also changed in a cyclic manner, identical to the changes in the leaves and air temperatures. The nightly averages of air, leaves, and dew-point temperatures inside the fiberglass greenhouse during the coldest month (January) were 16.6 ºC, 18.1 ºC, and 7.8 ºC, respectively. These averages inside the polyethylene greenhouses, respectively, were 15.0 ºC, 16.3 ºC, and 7.4 ºC. Therefore, the condensation substantially occurred on the inside cover of the two greenhouses because the leaf temperature was greater than the dew-point temperature of air.
6. The polyethylene greenhouse required a heat energy supply greater than that the fiberglass by 23.65 %. The mathematical model revealed that, the predicted heat energy supplied with respect to both the heat energy lost and heat energy gained was validated very well with that measured by an agreement of 99.0 %.
7. The total heat energy consumed for the fiberglass and polyethylene greenhouses utilising the solar energy system of greenhouse cucumbers provided 65.95 % and 55.68 %, respectively.
8. The microclimatic within the two adapted greenhouses were at or around the desired level during the daylight (26.8 ºC) and at night (16.7 ºC) particularly at the critical period (from 2:00 to 6:00 h) during winter season. Optimal vegetative growth rate, stem length, number of fruits being seated and fresh yield were achieved.
9. The fresh yield of cucumber crop per square meter of the floor surface area for the two greenhouses, respectively, was 9.851 and 7.363 kg/m^2, consequently, the fiberglass greenhouse substantially increased the fresh yield by 30.12 % as compared with the polyethylene greenhouse.

Ultimately, the control of the microclimatic that was provided, and maintained within the greenhouses at a the desired level, particularly during night in the cold winter, caused a substantial increase the quantity and marketable quality of the cucumber crop.

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NEWS

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The Reaper as an Alternative System for Litter Removal Inside Broiler Houses

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Abstract

A new test to identify a modified reaper has been developed for broiler litter removal. The present study describes in detail the efficacy of this new method on broiler litter removal efficiency. Tests were carried out to select the appropriate operating parameters for this purpose. The results of these experiments were graphed to show and examine the differences associated with the choice of the independent variable. It appears that the highest values of 1018.89 m^2/h effective field capacity and of 84.89 % field efficiency were achieved at operating conditions of 45.4 % w.b. litter moisture content, 1.2 km/h reaper travel speed and 2º shovel blade tilt angle. In contrast, the lowest values of 330.96 m^2/h effective field capacity and of 55.16 % field efficiency were achieved at the operating conditions of 35.7 % w.b., 0.6 km/h and 8º. It could be demonstrated that the differences between the highest and lowest values were of 207.8 and 53.9 % increment for the effective field capacity and field efficiency, respectively. Similar results were obtained for the remaining parameters. However, in this case, the differences between the highest and lowest values were of 19.30, 210.94, 124.21 and 210.64 % increment for the litter removal efficiency, reaper output, unit energy and unit operating cost, respectively. It was quite evident that, from cost estimates, the labor participation revealed the highest cost parameter percentage of 44.09. Contrariwise, the lowest cost parameter percentage of 10.23 was attributed to fuel and lubrication. In all circumstances, the equipment has proved efficient and cost effective during extensive use.

Introduction

Broiler (poultry) litter is a waste material that can be recognized as a combination of accumulated droppings (manure) and bedding material from poultry production. The common bedding materials are wheat hay, rice straw, rice and peanut hulls, shredded sugar cane, wood shavings, sawdust and other dry, absorbent, low-cost organic materials. Sand is also occasionally used as bedding. The Broiler litter is removed from poultry houses after the birds have been raised. It is a valuable source of minerals (4 % nitrogen, 1.56 % phosphorus and 2.3 % potassium) for soil fertilization and a biomass resource for bioenergy applications (Allam, in Arabic, 1994; McMullen *et al*., 2004; Fasina *et al*., 2006; and Bernhart *et al*., 2007). Most expansions of broiler houses, in Egypt, are only vertical expansions because of the decrease of agrarian plot. This has led to many obstacles in removing the litter, using the mechanized methods, from the ground of the multi-floor broiler houses after each production (rearing) cycle. Introduction of appropriate machinery is one of the major factors for reducing labor requirements and production costs (Alizadeh *et al*., 2007). This requires a suitable machine with qualities such as size, mass and performance to remove the litter. Therefore, it was an urgent question to make full use of the reaper in removing litter from the floor of these broiler houses. This can be easier when those broiler houses are provided with elevators to serve the higher floors in lifting fodders and rations. This system in its turn makes lifting the studied machine to the higher floors an easy task. The reaper (harvester) is a machine to cut (reap) grain crops such as rice, wheat and barley. It has the peculiarity of a simple configuration and reasonable structure, which is convenient for maintenance, with the advantages of small volume, lightweight, low energy consumption, stable performance, good reliability and strong applicability. Therefore, it is very suitable to small fields, mountainous areas and hills (Sahay, 2004 and FMMCR, 2008). So, the main goal of this paper is to maximize the reaper utilization in litter removal from the ground floor of broiler houses.

Materials and Methods

To meet the objectives of the current investigation, some parts of the reaper are replaced and modified to serve as an alternative system to remove the broiler litter and to maximize the utilization of the reaper in another purpose except harvesting.

Reaper (Harvester):

The original function of the reaper was to reap or harvest rice, wheat and barely. The crop is guided and conveyed to the right side by the conveyer belt. The reaper is powered by an attached engine. One person is required to orient the machine. It consists of a metal frame, a pair of rubber wheels, an engine, power transmission system and harvesting unit. The reaper is coupled with a number of hitch points on the orientation handle grip for adjusting its inclination with the ground level. This machine is discriminated, during its repair and maintenance, with the simplicity of untying and construction. For instance, the harvesting unit can be taken to pieces out of the reaper keeping all the remaining components constant. The whole specifications of the reaper are listed in **Table 1**.

Suggested Modifications:

In this paper, the harvesting unit was taken to pieces and replaced by a shovel with the purpose of removing litter from the ground floor of broiler houses. The local raw materials such as 2 mm thick iron sheets were employed to fabricate the shovel with for its bottom and 1 mm thick for the rest. The shovel bottom was covered with a rubber lining to reduce friction with the concrete floors of the farm, especially in the higher floors. The operating width, side width and height of the shovel were of 1.0, 0.56 and 0.40 m, respectively. Its heaped capacity was about of 0.15 m^3, estimated on the basis of shovel geometrical shape. The shovel was coupled with an unmoved knife along with its operating width. The side width of knife was of 6 cm. The shovel was fixed at the reaper chassis by means of two steel arms. In addition, there were a number of hitch points along the sides of the shovel and chassis for controlling and changing the shovel blade tilt angle with the ground level. The complete fixation of shovel with the reaper chassis was done using a proper wick that tied between the point above the middle of shovel and chassis. Emptying the shovel load was accomplished by reaper inclination to the forwards. Detailed specifications of the modi-

Fig. 1 Diagram of the experimented shovel

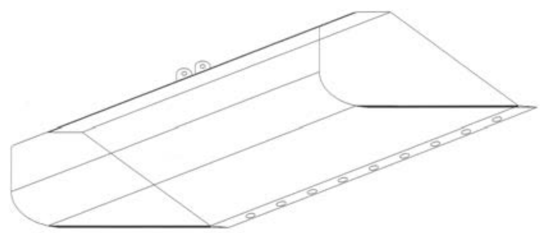


Fig. 2 A perspective of the alternative broiler litter removal system (the modified reaper)

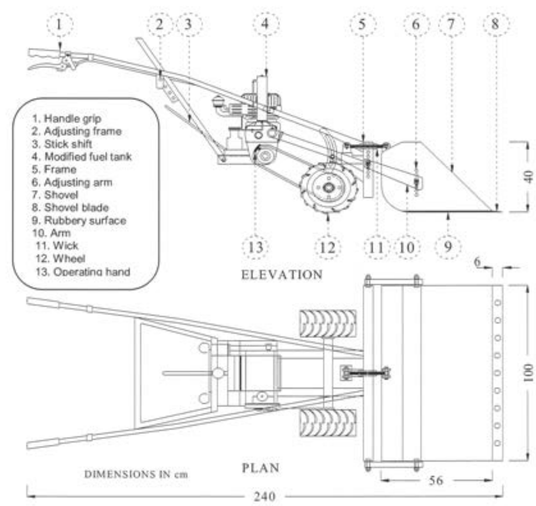


Table 1 Specifications of the original and modified reaper

Item	Reaper (harvester)	Reaper after modification
Function	Reap (harvest) rice, wheat and barley, etc.	Litter removal from the ground floor of broiler houses
Manufacturer	Japan	Japan (except the shovel)
Dimensions:		
Overall length, m	2.39	2.40
Overall width, m	1.47	1.20
Overall height, m	0.90	0.90
Mass, kg	116	117.5 (full empty shovel)
Engine:		
Type	4 - Cycle, air-cooled	
Model	GS 130-2CN	
Displacement	130 cc	
Fuel	gasoline	
Fuel tank volume	3 liters	0.5 liter
The modified part	Harvesting unit	Shovel
Ground contact device	A pair of rubber wheels	
Steering	Manual	

fied reaper are indicated in **Table 1**. Moreover, a diagram of the experimented shovel and a geometrical drawing of the modified reaper are illustrated in **Figs. 1** and **2**, respectively. The suggested modification in this study was fulfilled in one of the workshops at the Industrial City, Kafr Elsheikh Governorate.

Broiler Litter:

The investigated litter was a mixture of broiler droppings and chopped rice straw. The mean length of the chopped rice straw in litter ranged between 5 to 8 cm. Using a metal ruler, twenty five readings were taken at different and randomized positions of the farm ground to calculate the litter depth. The average litter depth was estimated to be about of 3.78 cm. The modified reaper was tested in removing litter after rearing cycle of broilers. The broiler farm consisted of three floors and its ground was concrete. The farm was equipped with a lever to elevate and lower the machine. Alongside, the removed litter was brought down by the lever. The broiler farm was located at Misseer Village, Kafr Elsheikh Governorate.

Studied Factors:

Performance characteristics of the modified reaper were demonstrated as affected by three operating factors as follows:

- Litter moisture content of 35.7, 40.6 and 45.4 % w.b.;
- Reaper travel speed of 0.6, 0.9 and 1.2 km/h and
- Shovel blade tilt angle of 2, 5 and 8º (0.0349, 0.0873 and 0.1396 rad), respectively (**Fig. 3**).

The optimum operating conditions of the modified reaper were evaluated and determined for all the levels of studied factors. Multiple regression analyses were made to represent the experimental data in linear form.

Measuring Instruments:

Moisture content of the broiler litter was determined using the oven method according to AOAC, 1985. Reaper travel speed was measured by a digital tachometer and expressed in rpm. After that, it was converted to linear speed in terms of km/h. Inclination of the shovel blade with the ground surface level was measured by a wooden protractor. A fuel tank with the capacity of about 0.5 liter was fabricated and connected with the reaper engine. This fuel tank consisted of tank, hand valve and graduated scale for monitoring the fuel consumption in terms of milliliters (**Fig. 4**). Consequently, the energy consumption could be easily calculated. A stopwatch was used for timing loading and whole lost time in which the effective field capacity could be estimated.

Fig. 3 Schematic drawing of the shovel blade tilt angles

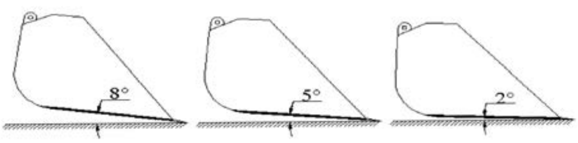
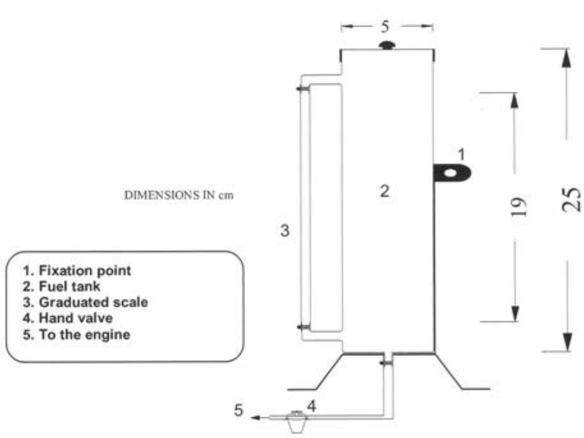


Fig. 4 The fuel consumption device



Procedures:

Effective field capacity (FC_E), m^2/h:

$$FC_E = 60 / T_l + T_i \quad (1)$$

where

T_l is the loading time, min/m^2 and

T_i is the summation of the lost time (adjusting, turning, discharging, repairing time, etc.), min/m^2.

Field Efficiency (FE), %:

$$FE = FC_E / FC_T \times 100 \quad (2)$$

where

FC_T is the theoretical field capacity, m^2/h.

$$FC_T = W \times S \times 10^3 \quad (3)$$

where

W is the shovel operating width, m and

S is the reaper travel speed, km/h.

Litter Removal Efficiency (LRE), %:

$$LRE = M_S / M_S + M_r \times 100 \quad (4)$$

where

M_S is the litter mass loaded into the shovel, kg and

M_r is the remaining litter mass on the ground floor after loading shovel, kg.

Reaper Output (RO), m^3/h:

$$RO = FC_E \times D \times LRE \quad (5)$$

where

LRE is the litter removal efficiency, decimal and

D is the mean depth of litter layer, m

Unit Energy, Kwh/m^3:

The power consumption requirements were calculated according to the formula of Hunt (1984) as follows:

Power consumption, (FC × p_f × LCV × 427 × η_m × η_{th}) / (3600 × 75 × 1.36) ....(6)

where

FC is the fuel consumption, l/h;

p_f is the fuel density, kg/l (for gasoline = 0.72);

LCV is the lower calorific value of fuel (11,000 kcal/kg);

427 is the thermo-mechanical equivalent, kg. m/kcal;

η_m is the engine mechanical efficiency, (for Otto engine = 85%) and

ηt_h is the engine thermal efficiency, (for Otto engine = 25%).

Then, the unit energy requirements can be calculated as follows:

Unit energy, kWh/m^3 = Power consumption (kW) / Reaper output (m^3/h) ....(7)

Total Cost, LE/h:

The total cost requirements of the modified reaper included fixed and operating costs. The declining balance method was used to determine the depreciation (Hunt, 1983). The unit operating cost could be estimated from the following formula:

Unit operating cost, LE/m^3 = (Reaper cost, LE/h) / (Reaper output, m^3/h) ....(8)

Results and Discussion

The idea of employing a simple reaper to serve as an alternative system for removing the broiler litter was introduced. The reaper performance parameters as affected by litter moisture content, reaper travel speed and shovel blade tilt angle were also investigated.

Effective Field Capacity:

Variation of the effective field capacity as affected by reaper travel speed at different levels of litter moisture content and shovel blade tilt angle is illustrated in **Fig. 5**. From the histograms of **Fig. 5**, it is obvious that effective field capacity increased with the increase in litter moisture content and reaper travel speed and the decrease in shovel blade tilt angle. At 35.7 % w.b. and 0.6 km/h, effective field capacity decreased from 356.10 to 330.96 m^2/h (−7.06 %) by increasing shovel blade tilt angle from 2 to 8º (+300 %). At 0.9 km/h and 5º, effective field capacity increased from 550.26 to 709.92 m^2/h (+29.0 2 %) by increasing litter moisture content from 35.7 to 45.4 % w.b. (+27.17 %). At 40.6 % w.b. and 8º, effective field capacity increased from 383.64 to 840.24 m^2/h (+119.02 %) by increasing reaper travel speed from 0.6 to 1.2 km/h (+100 %). The highest value of 1,018.68 m^2/h effective field capacity was obtained at 45.4 % w.b. litter moisture content, 1.2 km/h reaper travel speed and 2º shovel blade tilt angle. The lowest value of 330.96 m^2/h was obtained at 35.7 % w.b., 0.6 km/h and 8º. The difference between the highest and lowest values of effective field capacity could be estimated at 207.8 % increment.

Field Efficiency:

Variation of the field efficiency as affected by reaper travel speed

Fig. 5 Variation of effective field capacity and field efficiency as affected by reaper travel speed at different levels of litter moisture content and shovel blade tilt angle

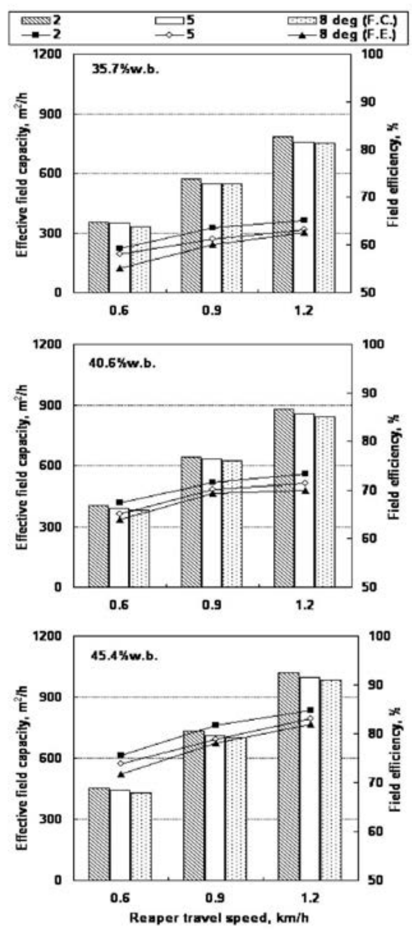
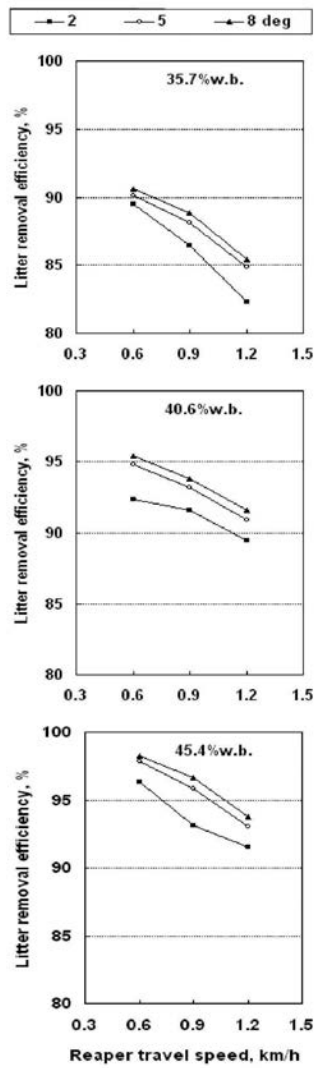


Fig. 6 The variation of litter removal efficiency as affected by reaper travel speed at different levels of litter moisture content and shovel blade tilt angle



at different levels of litter moisture content and shovel blade tilt angle is shown in **Fig. 5**. The general trend from **Fig. 5** is that field efficiency increased with the increase in litter moisture content and reaper travel speed and the decrease in shovel blade tilt angle. At 1.2 km/h and 8º, field efficiency increased from 62.51 to 81.86 % (+30.96 %) by increasing litter moisture content from 35.7 to 45.4 % w.b. At 45.4 % w.b. and 0.9 km/h, field efficiency decreased from 81.64 to 78.11 % (−4.32 %) by increasing shovel blade tilt angle from 2 to 8º. At 35.7 % w.b. and 5º, field efficiency increased from 58.14 to 63.11 % (+8.55 %) by increasing reaper travel speed from 0.6 to 1.2 km/h. The highest value of 84.89 % field efficiency was obtained at 45.4 % w.b., 1.2 km/h and 2º. The lowest value of 55.16 % was obtained at 35.7 % w.b., 0.6 km/h and 8º. The difference between the highest and lowest values of field efficiency could be estimated at 53.9 %.

Litter Removal Efficiency:

The variation of litter removal efficiency with the reaper travel speed at different levels of litter moisture content and shovel blade tilt angle is depicted in **Fig. 6**. From the curves of **Fig. 6**, it can be generalized that there was an increase in litter removal efficiency as the reaper travel speed decreased and both litter moisture content and shovel blade tilt angle increased. At 35.7 % w.b. and 1.2 km/h, litter removal efficiency increased from 82.35 to 85.43 % (+3.74 %) as shovel blade tilt angle increased from 2 to 8º. At 0.6 km/h and 8º, the litter removal efficiency increased from 90.57 to 98.24 % (+8.47 %) by increasing litter moisture content from 35.7 to 45.4 % w.b. At 40.6 % w.b. and 2º, litter removal efficiency decreased from 92.34 to 89.43 % (−3.15 %) as reaper travel speed increased from 0.6 to 1.2 km/h. The highest value of 98.24 % litter removal efficiency was obtained at 45.4 % w.b., 0.6 km/h and 8º. The lowest value of 82.35 % (the highest litter losses or the remaining of 17.65 %) was obtained at 35.7 % w.b., 1.2 km/h and 2º. The difference between the highest and lowest values of litter removal efficiency could be estimated by 19.30 %.

Reaper Output:

Effect of reaper travel speed on its output at different levels of litter moisture content and shovel blade tilt angle is demonstrated in **Fig. 7**. From the histograms of **Fig. 7**, it is revealed that reaper output increased with the increase in litter moisture content and its travel speed and the decrease in shovel blade tilt angle. At 35.7 % w.b. and 0.6 km/h, reaper output decreased from 12.04 to 11.33 m^3/h (−5.90 %) as shovel blade tilt angle increased from 2 to 8º. At 40.6 % w.b. and 2º, reaper output increased from 14.13 to 29.68 m^3/h (+110.05 %) by increasing its travel speed from 0.6 to 1.2 km/h. At 0.9 km/h and 5º, reaper output increased from 18.33 to 25.73 m^3/h (+40.37 %) as litter moisture con-

Fig. 7 Effect of reaper travel speed on its output at different levels of litter moisture content and shovel blade tilt angle

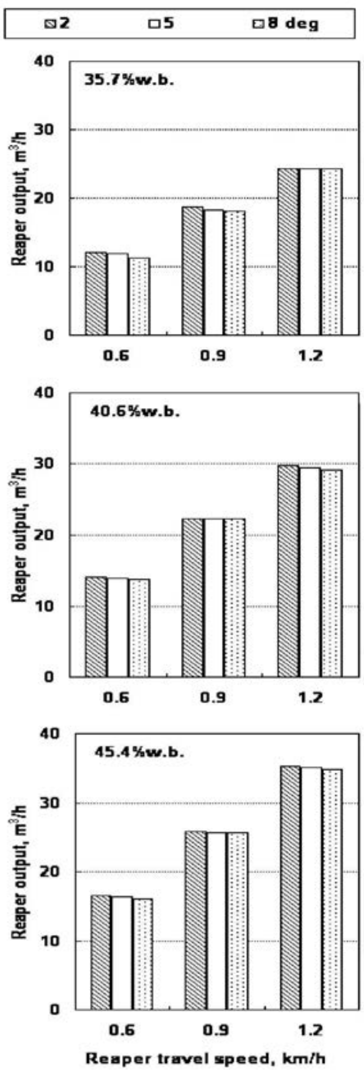
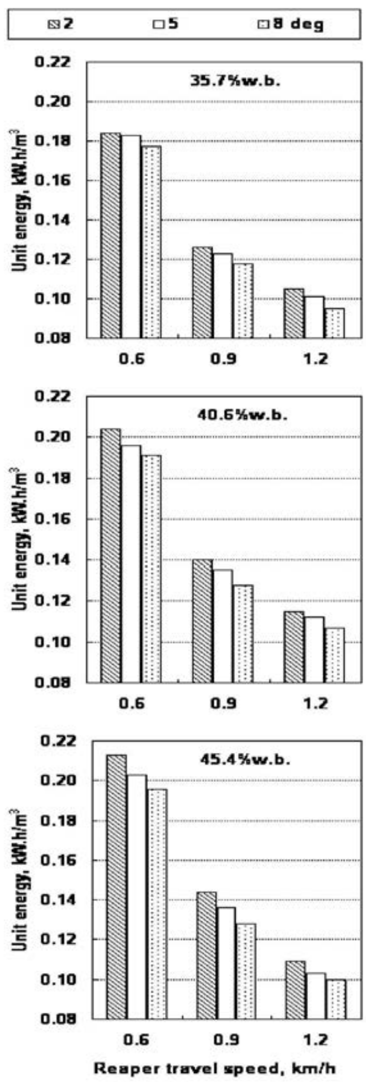


Fig. 8 Unit energy against reaper travel speed for different levels of litter moisture content and shovel blade tilt angle



tent increased from 35.7 to 45.4 % w.b. The highest value of 35.23 m^3/h reaper output was obtained at the conditions of 45.4 % w.b., 1.2 km/h and 2º. The lowest value of 11.33 m^3/h was obtained at 35.7 % w.b., 0.6 km/h and 8º. The difference between the highest and lowest values of reaper output could be estimated by 210.94 % increment.

Unit Energy:

Unit energy against reaper travel speed for different levels of litter moisture content and shovel blade tilt angle is illustrated in **Fig. 8**. From the histograms of **Fig. 8**, it can be generalized that unit energy decreased with the increase in reaper travel speed and shovel blade tilt angle and the decrease in litter moisture content. At 35.7 % w.b. and 1.2 km/h, unit energy decreased from 0.105 to 0.095 kWh/m^3 (−9.52 %) as shovel blade tilt angle increased from 2 to 8º. At 40.6 % w.b. and 5º, unit energy decreased from 0.196 to 0.112 kWh/m^3 (−42.86 %) as the reaper travel speed increased from 0.6 to 1.2 km/h. At 0.9 km/h and 2º, unit energy increased from 0.126 to 0.144 kWh/m^3 (+14.29 %) as litter moisture content increased from 35.7 to 45.4 % w.b. The highest value of 0.213 kWh/m^3 unit energy was obtained at the conditions of 45.4 % w.b., 0.6 km/h and 2º. Whilst, the lowest value of 0.095 kWh/m^3 was obtained at 35.7 % w.b., 1.2 km/h and 8º. The difference between the highest and lowest values of unit energy could be estimated at 124.21 %.

Unit Operating Cost:

Values of the unit operating cost at different levels of litter moisture content, reaper travel speed and shovel blade tilt angle are listed in **Table 2**. From the data of **Table 2**, it is indicated that unit operating cost increased by increasing shovel blade tilt angle and by decreasing both litter moisture content and reaper travel speed. At 35.7 % w.b. and 0.9 km/h, unit operating cost increased from 0.849 to 0.874 LE/m^3 (+2.94 %) as shovel blade tilt angle increased from 2 to 8º. At 40.6 % w.b. and 8º, unit operating cost decreased from 1.147 to 0.546 LE/m^3 (−52.40 %) as reaper travel speed increased from 0.6 to 1.2 km/h. At 1.2 km/h and 8º, unit operating cost decreased from 0.655 to 0.456 LE/m^3 (−30.38 %) as litter moisture content increased from 35.7 to 45.4 % w.b. The highest value of 1.401 LE/m^3 unit operating cost was obtained at the conditions of 35.7 % w.b., 0.6 km/h and 8º. The lowest value of 0.451 LE/m^3 was obtained at 45.4 % w.b., 1.2 km/h and 2º. The difference between the highest and lowest values of unit operating cost could be estimated by 210.64 % increment. Estimates of annual global cost for the modified reaper during litter removal operation are listed in **Table 3** and percentages of those cost parameters are depicted in **Fig. 9**. From **Fig. 9**, it can be demonstrated that the highest percentage of 44.09 cost parameter was belonged to labor. In contrast, the lowest one of 10.23 % cost parameter was belonged to fuel and lubrication. From **Table 3**, it can be noticed that the estimated operating cost of reaper was of 4,450 LE/year. The annual global cost was of 6,350.83 LE/year.The hourly reaper cost was estimated as 15.877 LE.

Six multiple linear regression equations were developed to describe the relationship between the reaper performance parameter as a dependent variable and litter moisture content, reaper travel speed and shovel blade tilt angle as independent variables. The following equation was presented:

$$IP = a_o + b_1M + b_2S + b_3\theta \quad (9)$$

where

IP is the investigated reaper performance parameter;

M is the litter moisture content, %w.b.;

S is the reaper travel speed, km/h;

θ is the tilt angle of the shovel blade, deg;

a_o is the y-intercept and

b_1, b_2, b_3 are the regression coef-

Table 2 Values of the unit operating cost at different levels of litter moisture content, reaper travel speed and shovel blade tilt angle

Litter moisture content, % w.b.	Reaper travel speed, km/h	Unit operating cost, LE/m^3		
		2º	5º	8º
35.7	0.6	1.318	1.337	1.401
	0.9	0.849	0.866	0.874
	1.2	0.652	0.653	0.655
40.6	0.6	1.123	1.133	1.147
	0.9	0.713	0.714	0.717
	1.2	0.535	0.540	0.546
45.4	0.6	0.962	0.968	0.993
	0.9	0.614	0.617	0.618
	1.2	0.451	0.452	0.456

Table 3 Estimation of annual global cost for the modified reaper during litter removal operation

No. of years (used before)	6
Remaining value, LE	6,411.54
Fixed cost, LE/year:	
a) Depreciation	1,131.45
b) Interest on investment, taxes, insurance and shelter	769.38
The fixed cost, LE/year	1,900.83
Operating hours/year	400
Operating cost, LE/year:	
a) Repairs and maintenance	1,000
b) Fuel + lubrication	650
c) Labor	2,800
The operating cost, LE/year	4,450
Reaper cost, LE/year	6,350.83
Reaper cost, LE/h	15.877

ficients.

As indicated in **Table 4**, accuracy of the six relationships was measured by determination coefficient (R^2).

Conclusion

This paper summarized the evaluation of a modified reaper and outlines compromises between cost, performance and its ease of operation. In conclusion, this work provided the following highlights:

- The effective field capacity and field efficiency of the modified reaper were directly proportional to the reaper travel speed and litter moisture content. They were inversely proportional to the shovel blade tilt angle.
- The highest percentage of 98.24 litter removal efficiency was achieved at 8º shovel blade tilt angle, 0.6 km/h reaper travel speed and 45.4 % w.b. litter moisture content. Furthermore, the highest value of 35.23 m^3/h reaper output was obtained at 2º, 1.2 km/h and 45.4 % w.b. operating conditions.
- The lowest consumed energy for the unit was at 0.095 kWh/m^3 at the operating conditions of 8º, 1.2 km/h and 35.7 % w.b. In addition, the lowest cost for removing one cubic meter of litter was at 0.451 LE at 2º, 1.2 km/h and 45.4 % w.b. operating conditions.

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Fig. 9 Percentage of cost parameters for the modified reaper in litter removal inside broiler houses

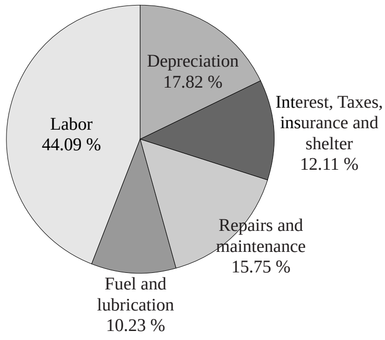

Table 4 Multiple linear regression Eqns., describing the broiler litter removal operation using the modified reaper

Performance Parameter	Y-Intercept (a_o)	Regression Coefficients			Determination Coefficient (R^2)
		b_1	b_2	b_3	
Effective field capacity, m^2/h	−751.99	+17.00	+800.02	−4.76	0.986
Field efficiency, %	−13.45	+1.85	+11.99	−0.55	0.982
Litter removal efficiency, %	+64.09	+0.80	−7.82	+0.40	0.954
Reaper output, m^3/h	−32.70	+0.78	+25.94	−0.07	0.978
Unit energy, kW.h/m^3	+0.23	+0.01	−0.15	−0.01	0.932
Unit operating cost, LE/m^3	+2.85	−0.03	−1.01	+0.01	0.944

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Excerpts of Annual Report of Department of Agriculture & Cooperation

In the first half of 2010-11, farm sector has achieved growth of 3.8 %, rebounding from −0.1 % and 0.4 % in the preceding two years. The full-year growth in farm sector is estimated to be 5.4 %. As per the Annual Report, the total expenditure in the first four years of the Eleventh Plan is estimated to be Rs. 44,413 crore, up from Rs. 14,952 crore in the entire 5 year period of the Tenth Plan. The Gross Capital Formation, or investment, in agriculture sector related to GDP in this sector has shown a substantial increasing trend from 15.8 % in 2005-06 to 22.3 % in 2009-10. In absolute terms, the capital formation in agriculture and allied activities in 2009-10 was over Rs. 1.3 lakh crore. As per the Central Statistical Organisation's estimates, the share of agriculture in the country's Gross Domestic Product (GDP) has fallen from 17.4 % in 2006-07 to 14.2 % in 2010-11. Agriculture Ministry feels that the falling share of agriculture in GDP is an expected outcome in a fast growing and structurally changing economy. (Sentences pasted from the original newsletter)

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Publisher : China Machinery Industry Press

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This book is the main target for government policy-making institutions, decision makers and agricultural machinery-related businesses engaged in market analysis, middle management, business planning and foreign investment institutions, trading companies, banks, securities, advisory services and research Agricultural project management unit.

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Output of Major Agricultural Machinery Products from January to December, 2009
(China Agricultural Machinery Industry Yearbook 2010)

Product name	Number of Enterprises (home)	Output Unit	Output in December, 2009	Output in December, 2008	Growth from Last Year	Output in 2009	Output in 2008	Growth from Last Year
Large Tractors	13	unit	6,567	3,343	96.44	74,718	57,171	30.69
Medium Tractors	33	unit	26,483	19,506	35.77	317,215	245,963	28.97
Small Tractors	142	unit	181,217	87,759	106.49	1,891,964	1,723,164	9.80
Motors	119	kW	93,243,547	30,265,512	208.09	848,090,071	651,817,231	30.10
Crop Harvest Machines	71	unit	58,674	33,906	73.05	632,269	406,903	55.39
Barnyard Machines	33	unit	35,318	17,791	98.51	379.387	253.412	49.71
Low-Speed Trucks	16	unit	59,086	56,176	5.18	1,070,026	957,772	11.72
Grain Processing Machines	177	unit	219,643	169,518	29.57	2,331,739	1,895,294	23.03
Feed Production Equipment	35	unit	32,533	16,583	96.18	250,248	191,874	30.42
Cotton Harvesters Machines	34	unit	4,565	3,300	38.31	40,205	36,157	11.20
Pumps	877	unit	7,305,897	6,021,446	21.33	69,312,907	69,540,077	−0.33

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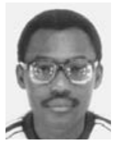
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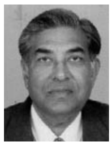
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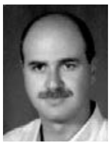
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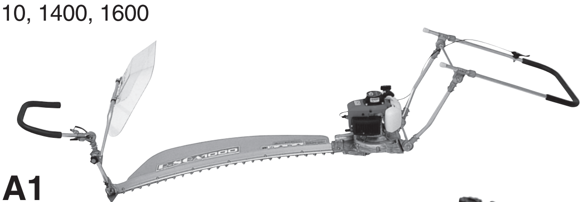

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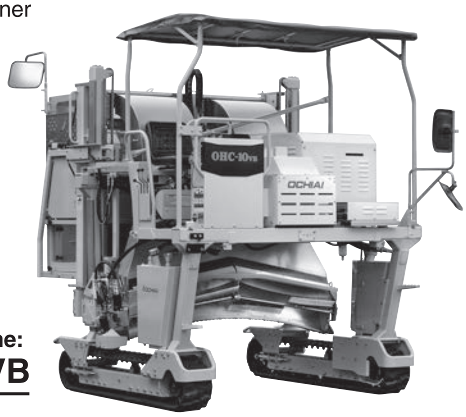

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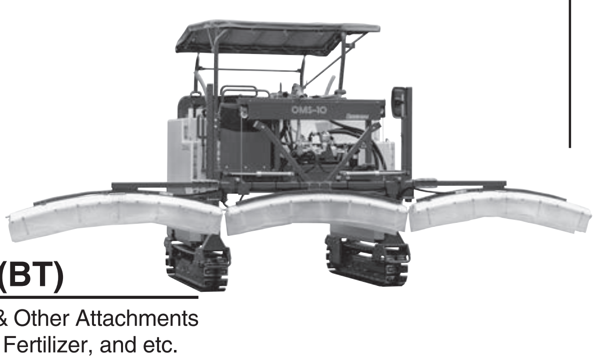

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