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Edited by

YOSHISUKE KISHIDA

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EDITORIAL

Recently, I visited India and China. In India, the Indian Society of Agricultural Engineering (ISAE) held the 46th annual convention from February 27th to 29th. At the same time, the International Symposium of Grain Storage was also held, so the timing was very good for me to visit. The congress was held at G.B.Pant University of Agriculture and Technology in a city called Pantnagar. It was the first university in India to be admitted as a Land Grant university. In the vast area of the premises, there were many research and educational institutes as well as experimental farm fields. My old friend Dr. Gajendra Singh was the chairman of ISAE, and it was an exciting trip since my last visit was a long time ago. There were various types of people there of all ages from children to adults; all very cheerful and energetic. I felt that this was because the country itself was becoming better along with the lives of people living there.

India has produced 400 thousand tractors with more than 30 horsepower. The agricultural production is growing as well and has overwhelmed the consumption. This means that India might be a food exporting country in the future. India will soon be the world's most populated country, with more than 1.5 billion people that will upgrade the demand for food and increase the food consumption. However, all the people concerned with agriculture in India say they can conquer this difficulty and become a food exporting country. There is a significant difference in the country's power compared to the time when I first published AMA more than 40 years ago.

The first of March the Indian Council of Agricultural Research (ICAR) held "Farmer's Day" in New Delhi. There was so much research exhibited there that I strongly felt that India would be one of the largest countries in agricultural research. India still needs to promote agricultural mechanization from various points of view. Indian people concerned with agricultural machinery will play a great role in this. What made me happy recently was the news that AMA was given a high rate as an essential magazine from the Indian agricultural institute called NAAS. I would like to express my appreciation for all the people who have contributed to AMA for a long time. We have received many well-written papers from India.

I visited China after visiting India. China is a country growing rapidly, as well as India. The governmental expense for agriculture has exceeded 1 trillion RMB, which is a growth of 183.9 billion RMB. The total food production is 571.2 million tons, which is 4.5 % growth from last year. This is the growth of eight consecutive years. This year, the Chinese government is planning to spend about 20 % more for agriculture. They are noting that agricultural mechanization is the most important issue. They have a specific reason for this. The population in the farming villages has decreased by 50 % from the past, and many young people tend to move to the urban areas. There are many farm villages where only elderly people, women and kids live. The average age of agricultural labor power in the farm villages has increased to 60 years old. The aging and the lack of manual labor power will definitely increase from now on. Under such conditions, China, a country with plenty of farmland, should promote agricultural mechanization to prevent agricultural production rate from declining. Last year, China produced 400 thousand tractors with more than 25 horsepower, 2 million tractors with less than 25 horsepower, and 1 million two-wheel tractors. This production volume was the highest in the world, but still, the Chinese government is aiming for 50 % domestic agricultural mechanization rate, so they need to produce more agricultural machinery.

To make full use of limited farmland, we need to promote more agricultural mechanization globally. AMA will give its best effort to realize this with all the readers, contributors and co-editors.

Yoshisuke Kishida
Chief Editor

April, 2012

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol.43, No.2, Spring 2012

A Two Row Subsoil Organic Mulch Cum Fertilizer Applicator

by
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Abstract

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

Introduction

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

Review of Literature

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

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

Details	Value
Over all dimensions, (L × B × H) mm	1,710 × 2,040 × 1,360
Size of main frame, (L × B) mm	1600 × 615
Hitch	Category I and Category II
No. of chisel plough bottom	2
No. of cross rails	2
Distance between shank, mm	Adjustable from 550 to 1,200
Number of organic manure hoppers	2
Number of fertilizer hoppers	2
Shape of hoppers	Trapezoidal
Volume of hopper, m^3	0.2
Type of metering mechanism for organic mulch	Auger feed
Type of metering mechanism for fertilizer	Stationery opening
Volume of hopper, m^3	0.04
Drive to agitator	From PTO shaft through sprocket and chain
Drive to auger and fertilizer metering device	From Ground wheel through sprocket and chain
Diameter of the ground wheel, mm	600

Methods and Materials

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

The front and side view of the tractor operated two row subsoil mulcher is shown in **Figs. 1** and **2**, respectively. The idle and operational view of the unit is shown in **Figs. 3** and **4**, respectively. For application of the recommended level of 20 t ha^{-1} mulch, a speed reduction ratio of 1.8 : 1 and 1.9 : 1 between the intermediate shaft and auger shaft was provided for raw coir pith and composted coir pith, respectively, and the prototype was calibrated. The performance of the prototype two row subsoil coir pith mulcher was evaluated in field No. 36 E in the Eastern block of Tamil Nadu Agricultural University, Coimbatore. A

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

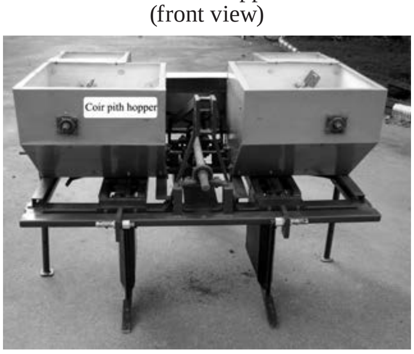


Fig. 2 Two row subsoil organic mulch cum fertilizer applicator (side view)

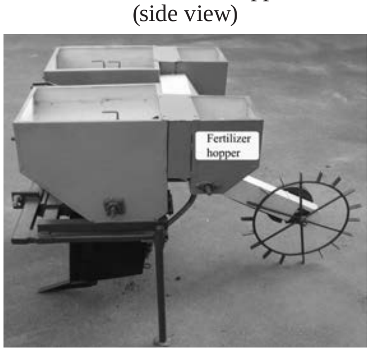


Fig. 3 Two row subsoil organic mulch cum fertilizer applicator fitted with trcator

total of 24 experiments were conducted in the experimental plot with optimized levels of variables. The size of the each plot was 6 × 3 m. The treatments for the evaluation of prototype two row subsoil coir pith mulcher are furnished below.

Treatments: 4

T_1: Composted coir pith mulch (20 t ha^{-1} and 350-450 mm depth)

T_2: Raw coir pith (20 t ha^{-1} and 350-450 mm depth)

T_3: Subsoiling (without mulch and 350-450 mm depth)

T_4: Control (No mulch)

Replications: 6

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

Results and Discussion

The difference in plant height between the control and mulched plots are clearly exhibited in **Fig. 5**. The plant height in composted coir pith, raw coir pith and subsoiled treatment plots was increased by 69.3, 54.8 and 46.4 percent over control. This was attributed to the proliferation of the roots resulting in a greater absorption of nutrient and water from the soil, causing higher plant height in mulched and subsoiled treatments (Taylor and Klepper, 1978). The effect of mulching and subsoiling on boll formation in the cotton crop during the maturity stage is depicted in **Fig. 6**. It was inferred that the boll formation in the composted coir pith, raw coir pith and subsoiled treatment plots was increased by 64.1, 38.5 and 26.5 percent over control. The subsoil application of raw and composted coir pith significantly influenced the root length as seen from **Fig. 7**. The root length in the composted coir pith, raw coir pith and subsoiled treatment plots was 32.4, 29.0 and 43.2 percent higher over control.

Fig. 4 Two row subsoil organic mulch cum ferti-lizer applicator (operational view)

Fig. 5 Effect of mulching and subsoiling on plant height

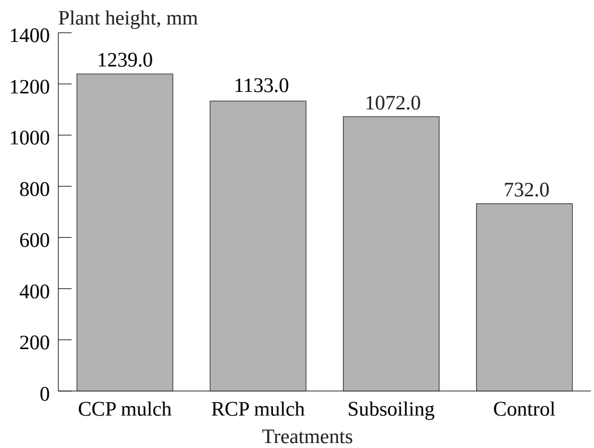


Fig. 6 Effect of mulching and subsoiling on boll formation

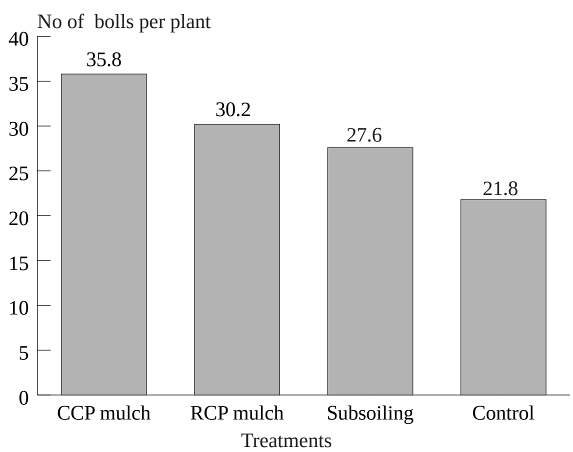
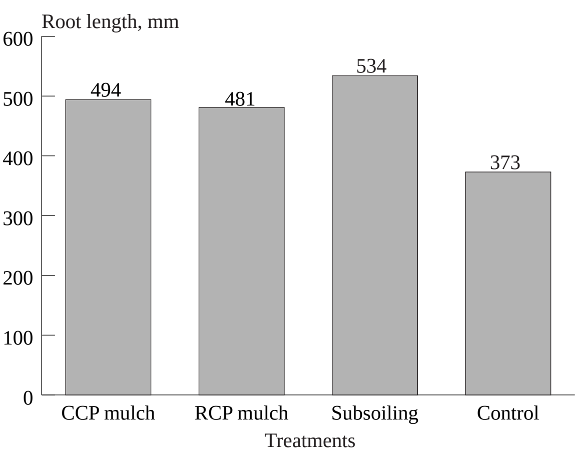


Fig. 7 Effect of mulching and subsoiling on root length



The root zone environment provided by the mulched plot was characterized by reduced mechanical impedance, more organic matter content and high moisture availability. This helped the root to grow and proliferate. The examination of the plants from the four treatments (**Fig. 8**) clearly showed that there was marked difference in root development between these four treatments. The major portions of the roots were formed along the plane of the vertical mulch, which clearly indicated the development of root in the trenches loosened by the mulcher. Subsoiling can mechanically aerate the soil at subsoil layers, which promotes better infiltration and absorption, and encourages crop root development (Xu and Mermoud, 2001).

The effects of mulching and subsoiling on root spread after the harvest of the cotton crop is depicted in **Fig. 9**. It is seen that the root spread was a maximum of 471 mm in composted coir pith followed by 434 mm in raw coir pith and 387 mm in subsoiled treatment plots. The better root spread in composted coir pith and raw coir pith mulched treatment plots was reflected with 21.4 and 12.1 percent higher values over subsoiling. Among the mulch materials, composted coir pith mulch was superior as shown by 8.3 percent more root spread than raw coirpith mulch.

Fig. 10 Soil moisture status for entire growth period of crop

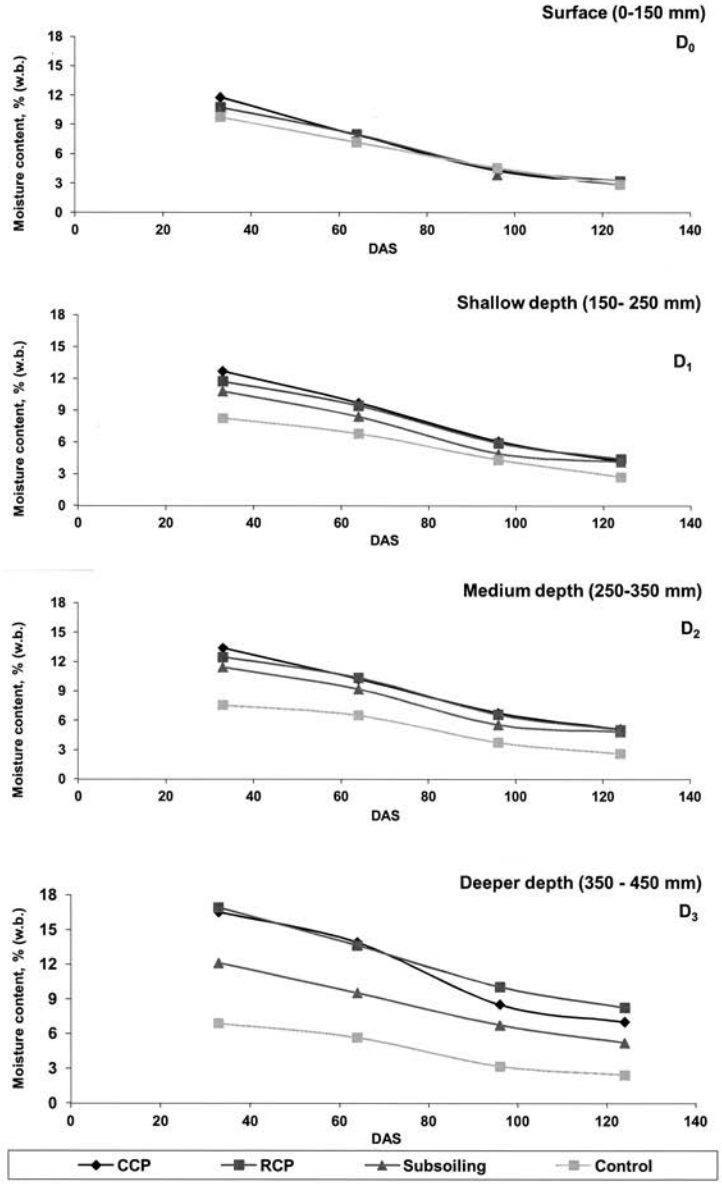


Fig. 8 Variation in root length and spread of cotton in treatment plots

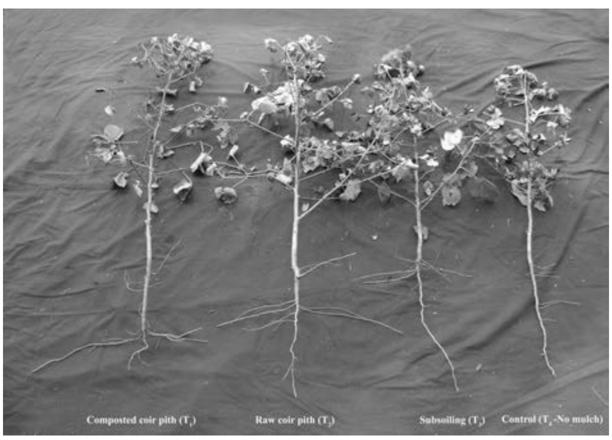
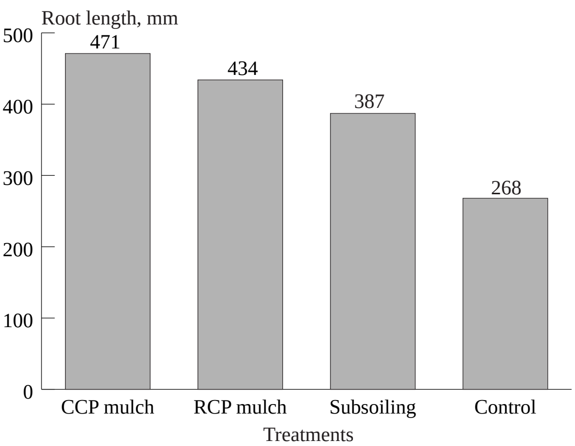


Fig. 9 Effect of mulching and subsoiling on root spread



The beneficial effect of composted coir pith was due to the combined influence of greater soil moisture availability and nutrient supply capacity created by composted coir pith application.

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

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

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

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

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

Conclusion

A tractor operated two row subsoil coir pith mulcher was developed for application of coir pith uniformly in the subsoil at desired rates of application and depths of placement. The performance of the prototype two row subsoil coir pith mulcher was evaluated in field conditions and compared with subsoiling and control plots. Plant height in composted coir pith, raw coir pith and subsoiled treatment plots increased by 69.3, 54.8 and 46.4 percent over control (no mulch). Plant height increased by 15.6 and 5.7 percent in composted coir pith and raw coir pith mulched treatment plots over subsoiling. Composted coir pith mulch registered 14.1 percent higher plant height than raw coir pith mulch. The boll formation in the composted coir pith, raw coir pith and subsoiled treatment plots

Fig. 11 Effect of mulching and subsoiling on root volume

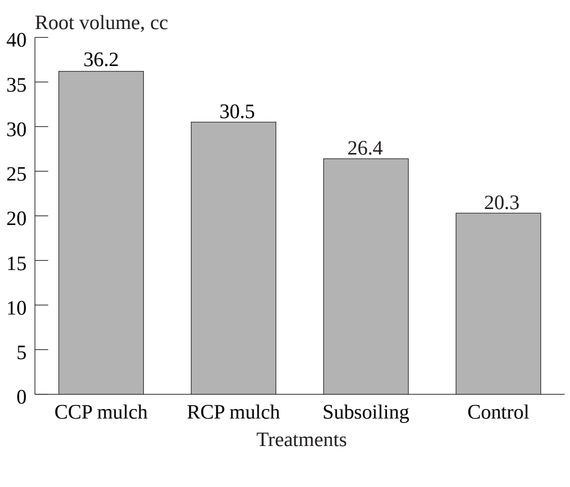
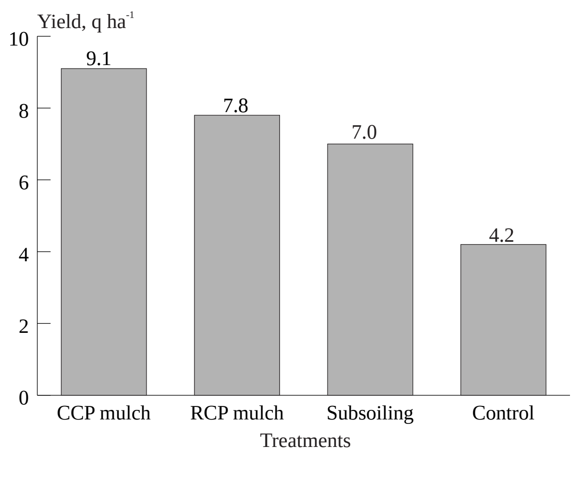


Fig. 12 Effect of mulching and subsoiling on yield



increased by 64.1, 38.5 and 26.5 percent over control. The number of bolls per plant increased by 29.4 and 9.4 percent for composted coir pith and raw coir pith mulched treatment plots over subsoiling. The composted coir pith mulch proved its superiority by recording 18.5 percent higher number of bolls than raw coirpith mulch. Subsoiled plot recorded the maximum root length of 534 mm than composted coir pith mulch (494 mm) and raw coir pith mulch (481 mm) treatment plots. The root length in the composted coir pith, raw coir pith and subsoiled treatment plots was 32.4, 29.0 and 43.2 percent higher over control. The better root spread in composted coir pith and raw coir pith mulched treatment plots was 21.4 and 12.1 percent higher than subsoiling. Composted coir pith mulch had 8.3 percent higher root spread than raw coirpith mulch. The root volume increased by 36.6 and 15.3 percent for composted coir pith and raw coir pith mulched treatment plots over subsoiling. The root volume of cotton was 12.1 percent more in composted coir pith mulch when compared to raw coir pith mulch. The yield in composted coir pith mulch, raw coir pith mulch and subsoiled treatment plots was 116.7, 85.7 and 66.7 percent higher than control. The yield was higher by 30.0 and 11.4 percent in composted coir pith and raw coir pith mulched treatment plots over subsoiling. The composted coir pith mulch recorded 16.8 percent increased cotton yield than raw coir pith mulch. The deep loosening and placement of mulch at the subsoil layer just below the plant rows resulted in reduction of soil strength, which helped the plant roots to penetrate deep into this layer and proliferate in vertical subsoil trenches. The recompaction of subsoil trenches was prevented due to the presence of raw and composted coir pith mulch.

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NEWS

◆ AMA has made a significant achievement in the rating by NAAS, National Academy of Agricultural Sciences.

Among the other known publications noted below, AMA has scored a high rate of 6.2.

The detail of the scores are as below.

1. Agricultural Mechanisation in Asia, Africa and Latin America (AMA) published by Farm Machinery Industrial Corporation & The Shin-Norinsha Company Limited (Tokyo, Japan) (6.2)
2. International Agricultural Engineering Journal published by Asian Association for Agricultural Engineering (Beijing, China) (4.9)
3. Journal of Institution of Engineers India (Agricultural Engineering) published by Institution of Engineers (Kolkata, India) (3.3)
4. (3.8) Agricultural Engineering Today, ISAE (India) (3.8)

Dr.Indra Mani Mishra, the secretary general of ISAE has noted that this is a new year gift. He convinced that with the cooperation of colleagues, they can achieve higher scores in the near future.

Temperature and Airflow Rate Effect on Artificial Ripening Process of Banana

by

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Abstract

The research was conducted in one of commercial refrigerators for ripening bananas (Musa Sapientium), in Kafr Elsheikh Governorate, Egypt during the season of 2006/2007. The need was to investigate the behavior of bananas during the ripening process at various temperatures and airflow rates. Both temperature and airflow rate were controlled by air distribution and adjusted inside the ripening room before loading bananas. This enhanced air temperature uniformity in both the vertical and horizontal dimensions. Additionally, this assisted in determining the most important changes in some physical properties of bananas that occured during the ripening process.

The deviations in the ripening room temperatures about their mean values were less with the especially designed air distribution duct. It, also, enhanced the uniformity of air distribution inside the ripening room and increased the effectiveness by 458.62 % at a ripening room temperature of 21 ºC. The shortest periods of banana ripening (shelf-life) were obtained at a ripening room temperature of 21 ºC and airflow rate of 0.3 m^3/s.kg. At an airflow rate of 0.3 m^3/s.kg, the shelf-life of bananas was increased from 12 to 25 days by decreasing ripening room temperature from 21 to 15 ºC. The optimum conditions for banana ripening were obtained at an airflow rate of 0.3 m^3/s.kg at all the ripening room temperatures under study. Generally, at constant airflow rate, the ripening room temperature of 21 ºC could be used to achieve a high rate of banana ripening. On the other hand, a ripening room temperature of 18 and 15 ºC could be used to achieve moderate and slow rates of banana ripening, respectively. Therefore, shelf-life of bananas could be considered a function of storage period for marketing or processing. Some physical properties such as ripening stage, mass loss percentage, pulp-to-peel ratio, pulp texture, pulp moisture content and pulp temperature were noticeably changed as the ripening process of banana fruits proceeded.

Introduction

In Egypt, the growing area of banana fruits is annually about 50.24 thousand fed (21.10 thousand ha). Its productivity is about 875.1Gg and production rate is 17.43 Mg/fed (41.49 Mg/ha) (CIHEAM, 2006). The design of a ventilation duct of constant cross-section is the discharge air from the duct be distributed uniformly along the duct's length. Uniformity of air discharge can be achieved by reducing the ratio of effective discharge area to duct cross-sectional area. Air temperature uniformity in both the vertical and horizontal dimensions may be considered a parameter in determining effectiveness of air distribution. Hot or cold spots within the building are also indicators of poor air temperature uniformity (Hellickson and Walker, 1983). Ripening involves a number of physical changes that occur in fruit. The most obvious change in many fruits during ripening is their external colour. The primary requirements for ripening rooms are that they should have a good temperature control system, good and effective air circulation, be gas tight, and have a good system for introducing fresh air. If rooms are not frequently ventilated ripening can be delayed, or abnormal ripening can occur (Thompson, 2003). Banana is one of the important fruits in the world. Due to its high carbohydrate content, it is considered a good source of energy. Because it is a climacteric fruit, it exhibits a well defined preclimacteric period after harvesting. During this period the fruit remains unripe due to its low respiration rate and also to small level of ethylene production (Marriott, 1980). This period can extend with decreasing temperature between 40-15 ºC. (Mootoo, 1990). After this period, the fruit respiratory rate increases. This increase is closely synchronized with ethylene evolution, peel chlorophyll breakdown, starch to sugar conversion, and pulp softening (Aked and Kyamuhongire, 1996). Ripening at low temperature (15 ºC) doubles the shelf-life of banana fruit and extends the utilization period for processing (Naser *et al*., 2001). Ripening of bananas is represented by a sequence of changes in the colour of the peel from green to yellow and the texture of the pulp. The duration of the shelf-life corresponds to the phase of development of the colour from stage No. 4 (more yellow than green) to stage No. 7 (yellow flecked with brown). It is a function of the storage conditions, principally the temperature. The rapidity of ripening increases as the temperature is raised. The fruits are maintained at the required ripening temperature, which is generally between 16 and 18 ºC (Gowen, 1995). The banana ripening rooms are subjected to intermediate temperatures, usually 18-20 ºC and high humidity. In ripening stage the skin colour changes from dark to light green and greenish yellow to bright yellow. Meanwhile the pulp softens outwards from the core and from the tip to stalk. The quality of bananas is improved if they are ripened properly at the right temperature and humidity (Samson, 1986). To ripened banana fruits, specially constructed ripening rooms are used where temperature, humidity as well as airflow rates are controlled. The storage temperature in a ripening room is maintained around 15 to 21 ºC, with a relative humidity of 85 %. The use of opened flame for heating should be avoided because carbon dioxide emitted during the combustion process will interfere with the ripening process. With bananas, as the ripening process proceeds, the rate of heat removal increases five or six times that of the initial rate. The refrigeration system for such products must be properly designed to remove the extra heat generated within the room. Therefore, high airflow rates are necessary for removal of heat given off by the product due to the respiration process. Other changes during ripening of bananas include change of skin colour from green to yellow, ease of peeling, increase in pulp-to-peel ratio, conversion of starch to sugar and softening of the pulp (Amalendu and Paul, 2001). Temperatures lower than 11.5 ºC lead to symptoms of cold damage. Above 35 ºC the development of the peel and of the pulp is desynchronized, with softening of the pulp proceeding faster than the colouring of the peel. This results in fruit with a soft pulp but a green peel. A reduction in relative humidity does not alter the respiratory rate, but shows changes in the mass relationship between pulp to peel, in the peel colour, and in pulp softening (Gowen, 1995). The maximum shelf-life (ripening period) of bananas is obtained by slow ripening at a range of 16-17 ºC (Marriott and Lancaster, 1983). Bananas can be harvested unripe and ripened artificially at a later stage. During ripening, its respiration rate increases dramatically over a short period of time. Also, fruit colour is a strong indicator of shelf-life (Jongen, 2002). The duration of "shelf-life" depends on storage temperature. To be assured of a firm pulp texture and bright yellow peel colour, green fruit must be ripened artificially at controlled temperatures. If initial ripening temperatures are too high (> 25 ºC), the fruit develops a soft, ripe pulp while the skin colour is only greenish yellow. Conversely, temperatures below 13 ºC cause chilling (Robinson, 1996). The movement of water from peel to pulp during ripening causes an increase in mass of the pulp (Wills *et al*., 1984).

The essential aim of this study is to investigate the possibility of utilizing an air distribution duct inside ripening room of bananas. Also, to investigate the behavior of ripening process for bananas at various values of temperatures and airflow rates inside a modified ripening room with the existing of air distribution duct. The specific objective of the investigation was to identify and suggest the most important physical properties of bananas which can be changed during its ripening process.

Materials and Methods

The experiment utilized a commercial refrigerator for banana ripening located in Kafr Elsheikh city,

Table 1 Technical specifications of the air conditioning unit

Unit	Model and value
Indoor unit (cooling only)	G+ITWG 024U
Indoor unit (heat pump)	G+IHWG 024U
Outdoor unit (cooling only)	G+OTS 025
Outdoor unit (heat pump)	G+OHS 025
Cooling capacity, kW	7.03
Heating capacity, kW	7.03
Cooling power consumption, W	2,700
Heating power consumption, W	2,500
Power supply, V/Ph/Hz	220-240/1/50
Refrigerant type	R22
Net mass, kg:	
Indoor unit	12.5
Outdoor unit	64.5

Egypt. The main parts of the modified commercial refrigerator were: ripening room, suction fan, air conditioning unit and air distribution duct.

Air Conditioning Unit:

The air conditioning unit was divided into three essential components: indoor unit, outdoor unit, and the operating board. It was adjusted to provide three different levels of air velocity. The operating board provided control at the required levels in the experiment for both temperature and relative humidity in the ripening room. The suction fan controls permitted automatic operation so that when the ripening room temperature was raised above the allowable level it would operate to keep the ripening room at the correct temperature level. The technical specifications of the air conditioning unit are listed in **Table 1**. A sketch of the experimental unit is shown in **Fig. 1**.

Air Distribution Duct:

For the purpose of the uniformity of distributing air temperature inside the ripening room and, in turn, increasing the effectiveness of the ripening process for bananas, a proper circular duct was designed and fixed with the indoor unit. This duct was made of plastic and was perforated through its lower and lateral sides with adequate orifices of 0.05 m in diameter. The air distribution duct was 0.25 m diameter and 2.13 m long. The duct expanded along the width of the ripening room and its end was closed near the room wall (**Fig. 2**). According to Hellickson and Walker (1983), the ratio of duct cross-sectional area to the effective discharge area was reduced by approximately 25 %. This reduction in cross-sectional area was mainly for obtaining an adequate uniformity of airflow along the length of air distribution duct.

Fig. 1 Schematic diagram of the commercial refrigerator used for banana ripening

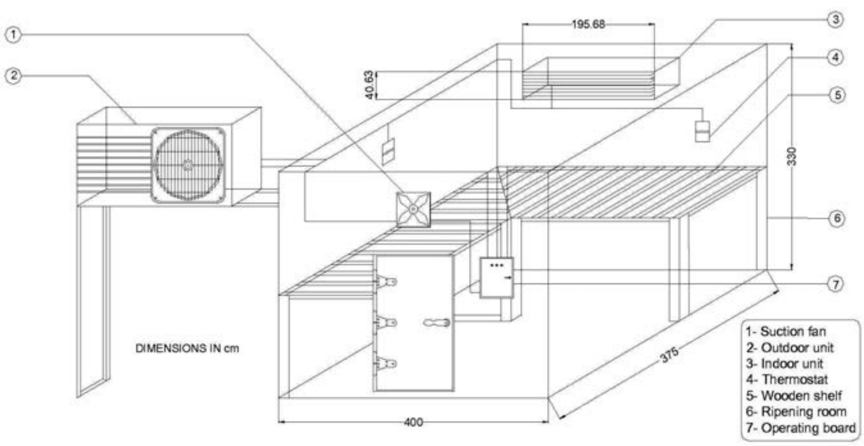
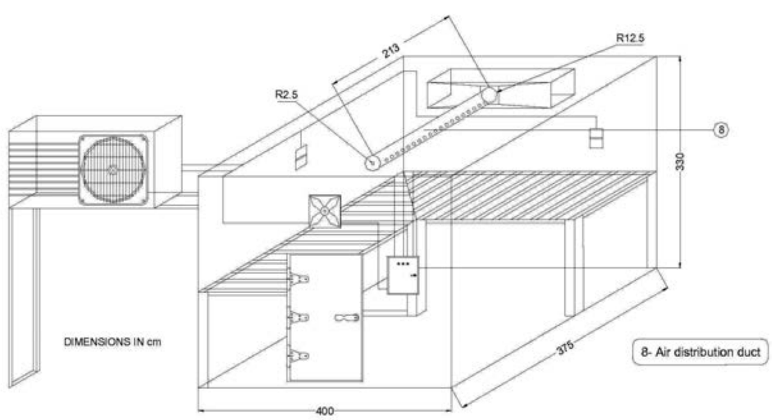


Fig. 2 Schematic diagram of the modified commercial refrigerator with an air distribution duct



Banana Fruits:

The quantity of bananas inside the ripening room was always variable. Therefore, it was weighed at each treatment throughout the period of experiment. Hence, the required airflow rate was estimated relative to each kilogram of bananas. The samples of bananas were transported, after each ripening stage, to Meet El-Deeba village. The physical properties of bananas were tested and identified at the laboratory of process engineering and handling, Rice Mechanization Center, Meet El-Deeba village, Kafr Elsheikh Governorate, Egypt. At the initiation of banana ripening, pulp-to-peel ratio, pulp texture and pulp moisture content were estimated. Their averaged values were: 1.57 ± 0.02, 10.75 ± 0.87 N/cm^2 and 63.36 ± 0.29 % w.b., respectively.

Investigated Variables:

Three different levels of airflow rate were used: 0.1, 0.3 and 0.5 m^3/s.kg. The ripening room temperatures were selected within the recommended range for banana ripening as: 21, 18 and 15 ºC. The relative humidity of the ripening room was steady during the period of study at 80 ± 3 %. Some physical properties of bananas (ripening stage, mass loss percentage, pulp-to-peel ratio, pulp texture, pulp moisture content and pulp temperature) were studied during the ripening process. The influence of ripening room temperature and airflow rate on ripening rate was investigated.

Measurements:

Before loading banana fruits into

the ripening room (ripening room without bananas), air temperature was measured inside the ripening room with and without the air distribution duct. Twenty-seven thermocouples were accurately distributed along the vertical and horizontal directions of the ripening room (**Fig. 3**). J-type thermocouples and a digital thermometer (Model HH-26J-USA), with a wide range of −80 to 760 ºC, were used for recording air temperature inside ripening room at the designed ripening room temperatures of 21, 18 and 15 ºC. Temperature measurements at each of the twenty-seven sensors were replicated three times and the averaged values taken. The standard deviation of those averaged values was calculated at every level of ripening room temperature under study. The designed airflow rates were obtained when the cross-sectional area of the indoor unit was automatically changed. Then, the required airflow rate could be calculated by multiplying both the cross-sectional area of the air distribution duct and the measured air velocity. A digital fan anemometer (Model: BR-B) was used for measuring the velocity of air.

The stage of banana ripeness was visually determined by a sequence of changes in banana peel colour. These changes were classified according to Ochse *et al.* (1961) that were prepared for commercial use. This classification included eight stages of peel colour and were translated to a numerical scale. The ripening stages of bananas with respect to peel colour, were: 1 = green; 2 = green trace of yellow; 3 = more green than yellow; 4 = more yellow than green; 5 = green tip; 6 = all yellow; 7 = yellow flecked with brown and 8 = yellow with large brown areas.

Mass loss percentage of bananas was calculated using the following formula:

$$m = (M_1 - M_2) / M_1 \times 100 \quad (1)$$

where:

m mass loss percentage, %;

M_1 mass of banana bunch before each ripening stage, kg and

M_2 mass of banana bunch after each ripening stage, kg.

Pulp-to-peel ratio was determined by the following relationship:

$$P = P_1 / P_2 \quad (2)$$

where:

P pulp-to-peel ratio, dimensionless;

P_1 mass of fruits pulp after each ripening stage, kg and

P_2 mass of fruits peel after each ripening stage, kg.

To estimate the moisture content of fruit pulp using a vacuum oven at 70 ºC to constant mass according to AOAC, 1985, the following equation was used:

$$MC = (M_1 - M_2) / M_1 \times 100 \quad (3)$$

where:

MC pulp moisture content, % w.b.;

W_1 mass of fruit pulp before each ripening stage, kg and

W_2 mass of fruit pulp after each ripening stage, kg.

A Japanese texture meter, (M-T-140) with an 8 mm diameter plunger, was used to measure changes in pulp texture during the ripening process that was expressed in terms of N/mm^2. The pulp temperature was measured by using the same apparatus described above for measuring ripening room temperatures. At each ripening stage, five thermocouples were installed in the ripening room and the mean values of pulp temperature were considered. A multiple regression analysis was made and regression equations of two independent variables were developed for some physical characteristics of bananas during the ripening process.

Fig. 3 Sensors for temperature recording along the length, width and height of repening room

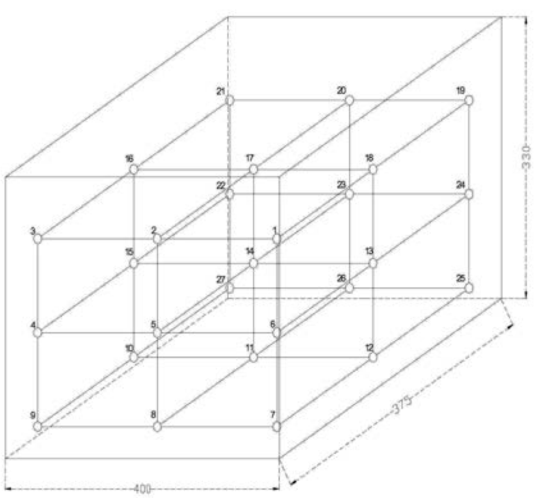
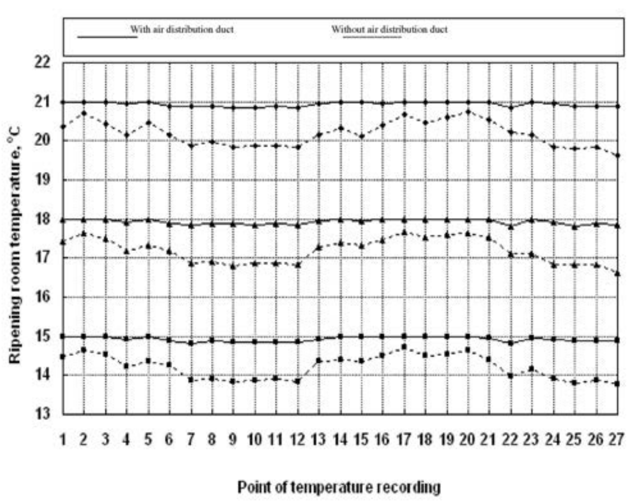


Fig. 4 Distributing air temperature along the vertical and horizontal directions of repening room with and without the air distribution duct



Results and Discussion

Air Distribution Effectiveness:

Effectiveness of air distribution inside the ripening room was highly influenced by the air distribution duct. As indicated in **Fig. 4**, the mean values of the ripening room temperatures were 14.93 and 14.21, 17.93 ºC and 17.19, 20.94 and 20.18 ºC inside the ripening room with and without the air distribution duct, respectively, at the investigated temperatures of 15, 18 and 21 ºC. It was obvious that the deviations of temperatures about their mean values were less with the air distribution duct than without. This meant that the air distribution duct raised the effectiveness of air distribution inside ripening room and, hence, ripening rate of bananas could be improved and accelerated. As shown in **Fig. 4**, the air distribution duct raised the uniformity effectiveness of air distribution inside ripening room by 395.24, 406.25 and 458.62 % at ripening room temperatures of 15, 18 and 21 ºC, respectively. This, in turn, enhanced the uniformity of air distribution for each finger of bananas and, therefore, maintained quality for processing or marketing. From the previously mentioned results, it was recommended that the designed air distribution duct be and fixed with the indoor unit and then bananas can be loaded and ripened under the modified conditions with the existing of air distribution duct.

Ripening Stage:

As shown in **Fig. 5**, the full ripening stage of bananas was at stage No. 8. As ripening room temperature decreased from 21 to 15 ºC, the ripening period was expanded from 12 to 25 days at constant airflow rate of 0.3 m^3/s.kg. The ripening period (shelf-life) of bananas was shortened by increasing airflow rate. At ripening room temperature of 21 ºC, the shelf-life was shortened from 14 to 13 days as the airflow rate increased from 0.1 to 0.5 m^3/s.kg. The shortest period of ripening was 12 days at an airflow rate of 0.3 m^3/s.kg and ripening room temperature of 21 ºC. This meant that, to obtain a quick

Fig. 5 Influence of ripening room temperature on ripening stage at different airflow rates

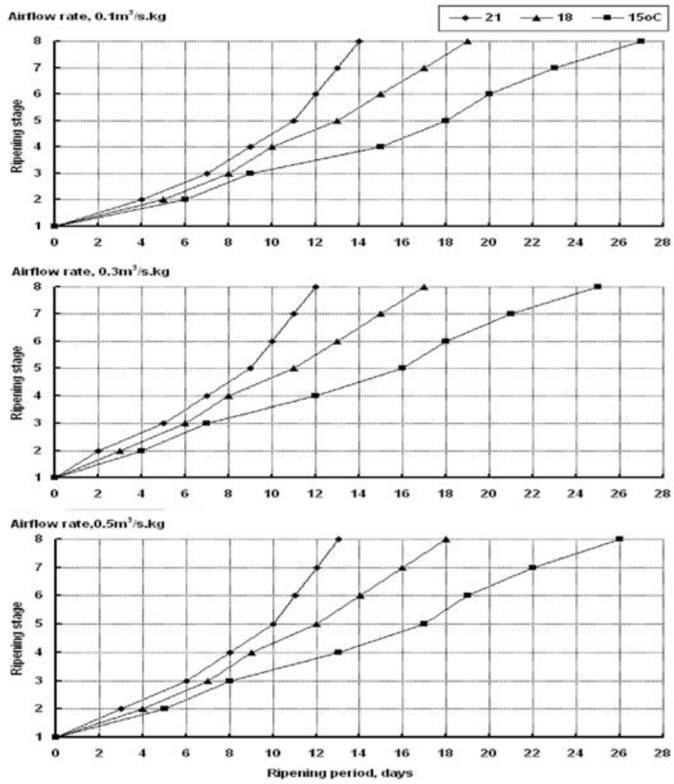
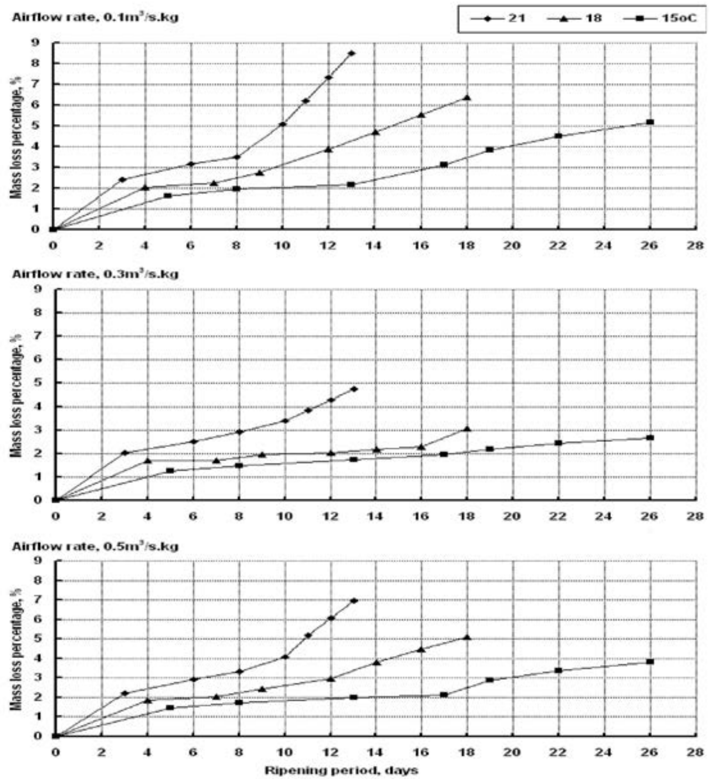


Fig. 6 Influence of ripening room temperature on mass loss percenatge at different airflow rates



ripening of bananas, 0.3 m^3/s.kg and 21 ºC could be used.

Mass Loss Percentage:

As shown in **Fig. 6**, the mass loss percentage increased gradually as the ripening process proceeded for all stages. At ripening stage No. 8 (full banana ripeness) as airflow rate increased from 0.1 to 0.3 m^3/s.kg, values of mass loss percentage decreased from 8.48 to 6.98 % at ripening room temperature of 21 ºC. At a constant airflow rate of 0.3 m^3/s.kg, the ripening room temperature decreased from 21 to 15 ºC and the reduction of mass loss percentage was 43.58 %. The lowest values of mass loss percentage were at an airflow rate of 0.3 m^3/s.kg at all values of ripening room temperatures.

Pulp-To-Peel Ratio:

The effect of ripening room temperature on pulp-to-peel ratio is shown in **Fig. 7**. At a constant airflow rate of 0.3 m^3/s.kg, the pulp-to-peel ratio increased from 2.34 to 3.79 while the ripening room temperature increased from 15 to 21 ºC. Also, when both airflow rate and ripening room temperature were constant, pulp-to-peel ratio gradually increased during ripening of bananas according to Wills *et al*. (1984) and Amalendu and Paul (2001). As the ripening room temperature was held constant at 21 ºC, the pulp-to-peel ratio increased from 2.01 to 3.79 as airflow rate increased from 0.1 to 0.3 m^3/s.kg.

Pulp Texture:

Pulp texture was highly affected by ripening room temperature and airflow rate as shown in **Fig. 8**. Pulp texture of bananas was strongly decreased from 10.75 to 0.48 N/cm^2, at a ripening room temperature of 21 ºC and airflow rate of 0.3 m^3/s.kg, as bananas ripened from stage No. 1 to stage No. 8 according to Amalendu and Paul (2001). Whereas, when the ripening room temperature was raised from 15 to 21 ºC, at a constant airflow rate of 0.3 m^3/s.kg, the banana pulp texture lowered from 0.98 to 0.48 N/cm^2. Pulp texture decreased from 0.97 to 0.72 N/cm^2 at a constant ripening room temperature of 18 ºC, when airflow rate

Fig. 7 Influence of ripening room temperature on pulp-to-peel ratio at different airflow rates

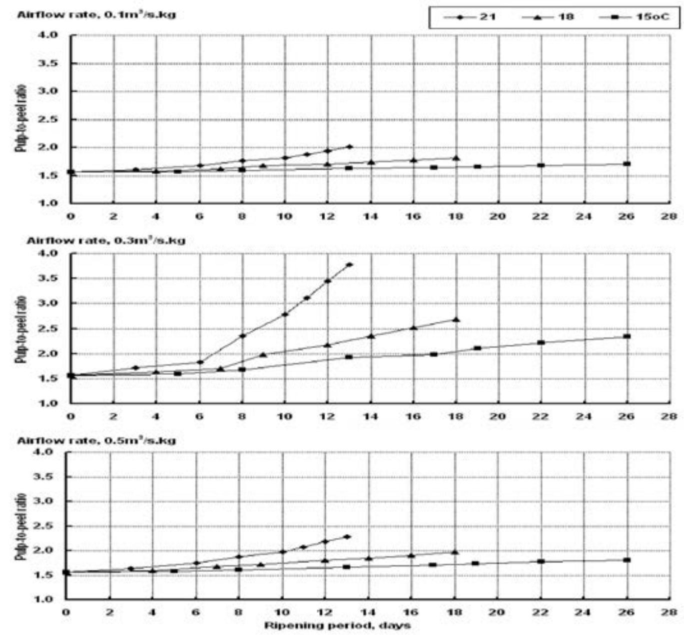


Fig. 8 Influence of ripening room temperature on pulp texture at different airflow rates

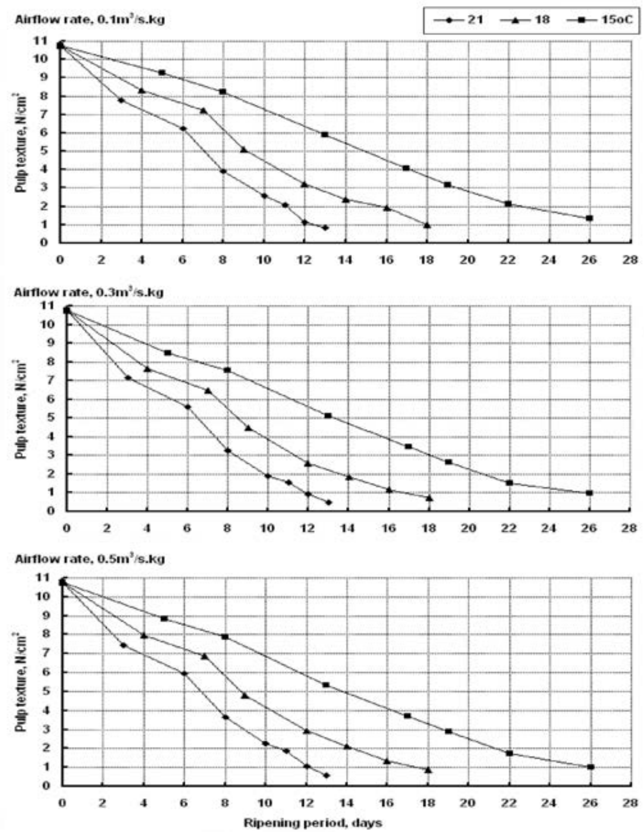


Table 2 Changes in physical properties of bananas during its ripening process as affected by both of ripening room temperature and airflow rate

Property	Airflow rate, m³/s.kg	Ripening room tempe-rature, ºC	Ripening stages, (1=green, 2=green trace of yellow, 3=more green than yellow, 4=more yellow than green, 5=green tip, 6=all yellow, 7=yellow flecked with brown and 8=yellow with large brown areas, Ochse *et al.*, 1961)							
			1	2	3	4	5	6	7	8
Ripening period, days	0.1	21	0.0	4	7	9	11	12	13	14
		18	0.0	5	8	10	13	15	17	19
		15	0.0	6	9	15	18	20	23	27
	0.3	21	0.0	2	5	7	9	10	11	12
		18	0.0	3	6	8	11	13	15	17
		15	0.0	4	7	12	16	18	21	25
	0.5	21	0.0	3	6	8	10	11	12	13
		18	0.0	4	7	9	12	14	16	18
		15	0.0	5	8	13	17	19	22	26
Mass loss percentage, %	0.1	21	0.0	2.41	3.17	3.51	5.10	6.22	7.35	8.48
		18	0.0	2.05	2.23	2.74	3.86	4.70	5.54	6.38
		15	0.0	1.63	1.94	2.17	3.14	3.82	4.50	5.19
	0.3	21	0.0	2.03	2.53	2.93	3.40	3.85	4.30	4.75
		18	0.0	1.69	1.72	1.95	2.05	2.18	2.31	3.08
		15	0.0	1.25	1.47	1.73	1.96	2.20	2.44	2.68
	0.5	21	0.0	2.21	2.94	3.32	4.06	5.18	6.08	6.98
		18	0.0	1.86	2.03	2.46	2.97	3.81	4.47	5.12
		15	0.0	1.45	1.75	1.98	2.11	2.88	3.36	3.83
Pulp-to-peel ratio, dimensionless	0.1	21	1.57	1.61	1.68	1.76	1.82	1.88	1.94	2.01
		18	1.57	1.58	1.62	1.68	1.71	1.74	1.78	1.82
		15	1.57	1.57	1.59	1.63	1.64	1.66	1.68	1.70
	0.3	21	1.57	1.72	1.83	2.35	2.78	3.12	3.45	3.79
		18	1.57	1.63	1.71	1.98	2.18	2.35	2.52	2.69
		15	1.57	1.59	1.68	1.93	1.99	2.10	2.22	2.34
	0.5	21	1.57	1.63	1.75	1.88	1.97	2.08	2.18	2.29
		18	1.57	1.59	1.67	1.72	1.80	1.85	1.91	1.97
		15	1.57	1.58	1.61	1.66	1.71	1.73	1.77	1.81
Pulp texture, N/cm²	0.1	21	10.75	7.78	6.26	3.91	2.58	2.08	1.16	0.83
		18	10.75	8.34	7.21	5.12	3.24	2.38	1.93	0.97
		15	10.75	9.27	8.25	5.89	4.07	3.16	2.11	1.35
	0.3	21	10.75	7.17	5.62	3.25	1.89	1.57	0.93	0.48
		18	10.75	7.62	6.49	4.48	2.59	1.86	1.18	0.72
		15	10.75	8.47	7.54	5.11	3.48	2.65	1.49	0.98
	0.5	21	10.75	7.45	5.95	3.63	2.28	1.86	1.05	0.59
		18	10.75	7.95	6.88	4.81	2.91	2.12	1.33	0.86
		15	10.75	8.86	7.87	5.32	3.68	2.87	1.75	1.02
Pulp moisture content, % w.b.	0.1	21	63.36	64.41	65.93	67.46	68.78	70.18	71.59	72.99
		18	63.36	63.95	64.97	66.35	67.78	68.21	69.23	70.25
		15	63.36	63.21	64.46	64.79	65.38	65.95	66.53	67.11
	0.3	21	63.36	65.19	66.59	68.28	69.89	71.51	73.12	74.74
		18	63.36	64.61	65.68	66.87	68.03	69.19	70.88	71.51
		15	63.36	64.28	65.11	66.21	66.88	67.75	68.63	69.98
	0.5	21	63.36	64.78	66.21	67.87	69.35	70.88	72.40	73.94
		18	63.36	64.28	65.35	66.78	67.83	68.99	70.16	71.32
		15	63.36	63.93	64.83	65.18	65.97	67.31	68.13	69.25
Pulp temperature, ºC	0.1	21	-	21.87	22.68	23.52	24.05	23.41	22.68	22.49
		18	-	18.73	19.59	20.25	20.84	20.37	19.52	19.39
		15	-	15.72	16.56	17.24	17.82	17.33	16.49	16.34
	0.3	21	-	21.31	22.25	22.71	23.52	22.98	22.35	22.16
		18	-	18.22	19.43	19.62	20.31	19.95	19.25	19.11
		15	-	15.21	16.4	16.61	17.29	16.91	16.22	16.06
	0.5	21	-	21.12	21.91	22.43	22.93	22.56	21.94	21.56
		18	-	18.11	18.75	19.23	19.87	19.42	18.78	18.26
		15	-	15.1	15.72	16.22	16.85	16.38	15.75	15.21

increased from 0.1 to 0.3 m^3/s.kg. The lowest values of pulp texture of bananas were at an airflow of 0.3 m^3/s.kg at all of ripening room temperatures.

Pulp Moisture Content:

During ripening of bananas, from stage No. 1 to stage No. 8, the moisture was transferred from peel to pulp according to Wills *et al.* (1984). **Table 2** shows that as bananas ripened from stage No. 1 to stage No. 8 the moisture content of pulp gradually increased at all airflow rates and ripening room temperatures. As shown in **Fig. 9**, when airflow rate was constant at 0.3 m^3/s.kg, the moisture content of banana pulp increased from 69.98 to 74.74 % w.b. as the ripening room temperature increased from 15 to 21 ºC. It, also, indicated that, at constant ripening room temperature of 15 ºC, the pulp moisture content increased from 67.11 to 69.25 % w.b. as airflow rate raised from 0.1 to 0.5 m^3/s.kg. At a constant airflow rate of 0.3 m^3/s.kg and constant ripening room temperature of 21 ºC, the moisture content of banana pulp gradually increased from 63.36 to 74.74 % w.b. as reripening progressed from stage No. 1 to stage No. 8. The highest values of pulp moisture content were at an airflow rate of 0.3 m^3/s.kg at all ripening room temperatures.

Pulp Temperature:

As shown in **Fig. 10** and **Table 2**, the pulp temperature of bananas dramatically increased until stage No. 6 because bananas gained maximum respiration rate at this stage. When the airflow rate and ripening room temperature were constant at 0.1 m^3/s.kg and 21 ºC, the pulp temperature of bananas increased from 21.87 to 22.49 ºC as the ripening process proceeded from stage No. 2 to stage No. 8. Also, pulp temperature gradually increased by as ripening room temperature increased and airflow rate reduced. At a ripening room temperature of 21 ºC, the pulp temperature decreased from 22.49 to 21.56 ºC, at ripening stage No. 8, as airflow rate raised from 0.1 to 0.5 m^3/s.kg. When airflow was constant at 0.3 m^3/s.kg and at ripening stage No. 8, the pulp temperature increased from 16.06 to 22.16 ºC by increasing the ripening room temperature from 15 to 21 ºC. The lowest values of pulp temperature were at an airflow rate of 0.5 m^3/s.kg at all ripening room temperatures.

The regression analysis for the data provided multiple linear regression equations for all of the physical properties of bananas for ripening stage No. 8. The values of regression coefficients and their corresponding values of determination coefficients are listed in **Table 3**. Ripening stage No. 8 was directly considered for developing such linear regression equations because the bananas reached their maximum ripening rate and the ripening process of bananas was complete at this stage. Similar regression coefficients were obtained for all banana properties at every stage of ripening and, hence, many multiple regression equations could be developed. In short, the ripening rate of bananas was highly significant as affected by both of airflow rate and ripening room temperature at all of the ripening stages. The ripening process of bananas at various indicators was well described by the following general multiple linear regression equation:

$$Y = a_o + b_1 X_1 + b_2 X_2 \quad (4)$$

where:

Y indicator;
X_1 airflow rate, m^3/s.kg;
X_2 ripening room temperature, ºC;
a_o Y-intercept and
b_1, b_2 regression coefficients.

Fig. 9 Influence of ripening room temperature on pulp moisture content at different airflow rates

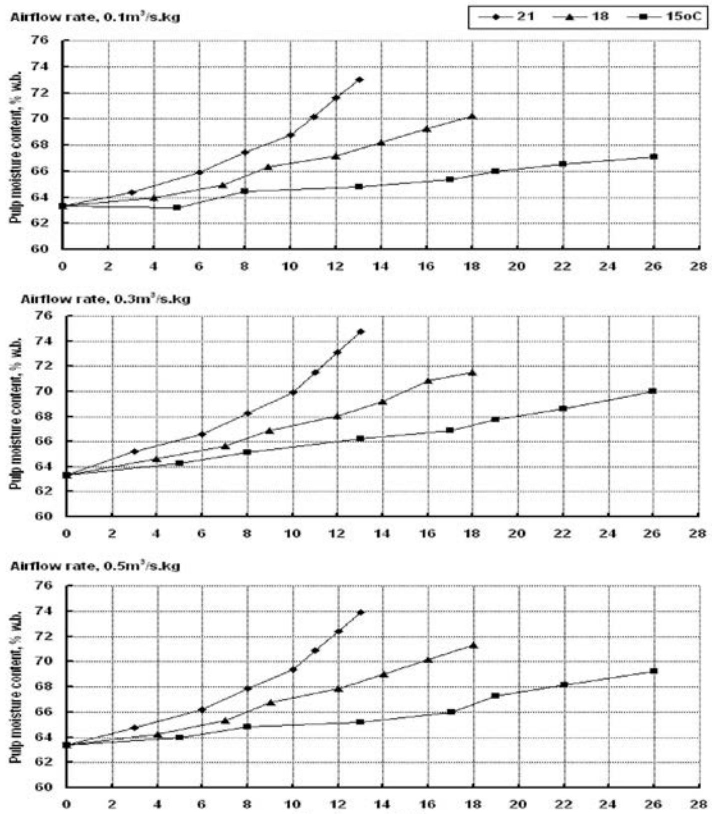


Table 3 Regression equation describing the ripening process for bananas at ripening stage No. 8.

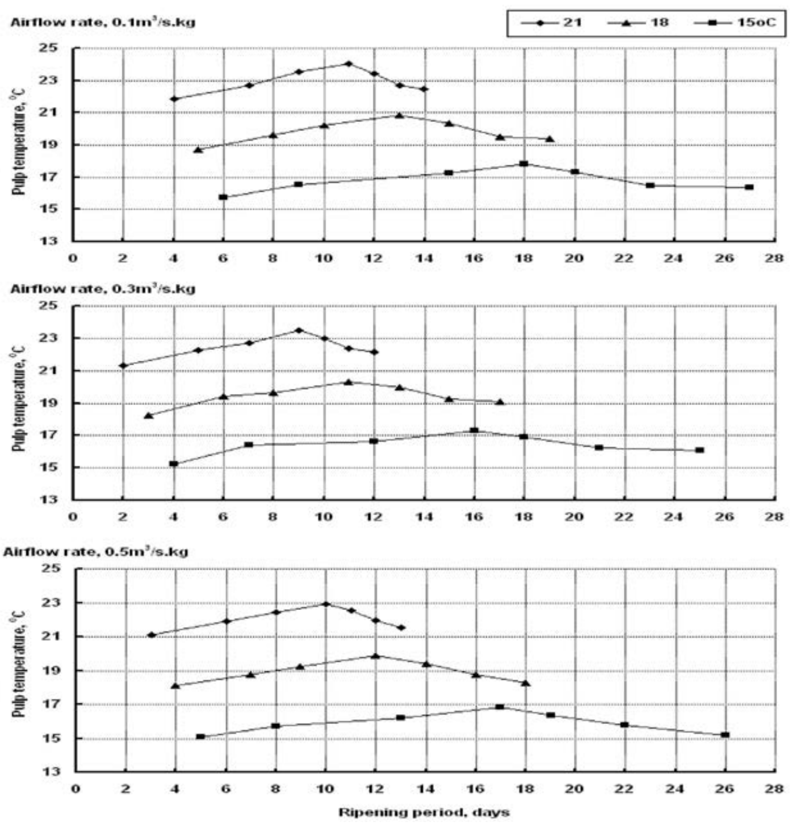
Indicator	Y-intercept	Regression coefficients		Determination coefficient (R^2)
	a_o	b_1	b_2	
Shelf-life, days	+ 58.750	− 2.500	− 2.167	0.966
Mass loss percentage, %	− 2.274	− 3.433	+ 0.473	0.555
Pulp-to-peel ratio, dimensionless	− 0.106	+ 0.450	+ 0.124	0.261
Pulp texture, N/cm^2	+ 2.487	− 0.567	− 0.081	0.807
Pulp moisture content, % w.b.	+ 54.862	+ 3.467	+ 0.852	0.909
Pulp temperature, ºC	+ 1.151	− 2.658	+ 1.033	0.998

Conclusion

The essential points of the investigation can be concluded as follows:

- The designed air distribution duct inside the banana ripening room raised the air distribution uniformity effectiveness by 395.24, 406.25 and 458.62 % at ripening room temperatures of 15, 18 and 21 ºC, respectively.
- The ripening period of bananas was shortened by 52 % by increasing the ripening room temperature from 15 to 21 ºC, while, by increasing airflow rate from 0.1 to 0.3 m^3/s.kg, it was reduced only by 14.286 %.
- For achieving a quick ripening of bananas, an airflow rate of 0.3 m^3/s.kg and ripening room temperature of 21 °C could be recommended to accomplish this process successfully.
- By proceeding the ripening process of bananas from stage No. 1 to stage No. 8, mass loss percentage, pulp-to-peel ratio, pulp moisture content and pulp temperature gradually increased, while pulp texture was strongly decreased.
- The lowest values of mass loss percentage and pulp texture were obtained at an airflow rate of 0.3 m^3/s.kg at all ripening room temperatures. Conversely, the highest values of pulp moisture content were at an airflow rate of 0.3 m^3/s.kg.
- All of the physical properties of bananas were noticeably affected by changing both airflow rate and ripening room temperature. From the above-mentioned results, it could be seen that, at any airflow rate within the recommended range for ripening bananas, the ripening room temperatures of 21, 18 and 15 ºC could be successfully used for achieving high, moderate and slow ripening rates, respectively.

Fig. 10 Influence of ripening room temperature on pulp temperature at different airflow rates



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■■

NEWS

◆ Is Biogas Efficient as the Tractor Fuel of the Future?

Biogas is basically made out of methane, produced when organic matters, such as livestock manure and plant material are digested by microorganisms in an anaerobic digester without oxygen. Methane burns easily and can be used directly for heating or to fuel an engine, and most of the anaerobic digesters on UK farms power engines driving generators for electricity used on the farm, with the surplus sold to the National Grid.

Biogas is one of the strongest candidates for on-farm production of renewable energy, but it could also play a big role as a tractor fuel for farmers seeking energy self-sufficiency and an escape from rising diesel costs. Two manufacturers, Steyr and Valtra, have already demonstrated tractors equipped to burn biogas, while New Holland has also shown an experimental tractor that could rely indirectly on biogas.

One of the problems biogas tractor engineers are facing is how to provide enough storage capacity to carry the gas. This is because biogas is difficult to compress and an hour's work would need much more tank capacity for gas than for diesel.

There are many alternative fuels other than biogas. The ones noted below are some of them.

a) Alcohol from Potatoes

American research in 1910 found out that one acre of potatoes can produce 600 US gallons of alcohol, which is enough to plough 200 acres using spark ignition tractor. Potato alcohol was considered as a possible fuel for tractors in Britain in the Second World War but the idea was abandoned.

b) Producer Gas from Wood

Shortages during the First World War encouraged French and German experiments with alternative fuels. Producer gas, a nitrogen and carbon monoxide mix released when wood is heated without oxygen to 1,000 ºC, was favoured in both countries. Gas kits were used on tractors during the Second World War, too.

c) Biodiesel

It is made from oilseed rape, RME or rape-methyl-esther. It has emerged as the biofuel success story. It can fuel most diesel engines without modification and is used either on its own or more usually in a mix with diesel fuel.

d) Fuel Cells

Tried in the past by Allis Chalmers, it'S new Holland that is flying the flag at the moment with its NH_2 hydrogen-powered tractor. Using farm-produced electricity to extract hydrogen from water makes for an ecologically neat set-up.

New tractor fuels are needed for sustainable agriculture in the future, and we need more researches done to make full use of them.

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Potential of Micro-Hydropower Generation Systems in India

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Abstract

Large-scale hydro-electric power has been used worldwide for a long time to generate huge amounts of power from water stored behind massive dams. Small-scale hydro power has been used for hundreds of years for manufacturing, including milling grain, sawing logs and manufacturing cloth. However, it can also be used without a dam to generate electricity for home scale remote power systems. These so-called micro-hydro installations can be a very good power source, as they produce electricity round the clock. Over the last few decades, there has been a growing realization in developing countries that micro hydro has an important role to play in the economic development of remote rural areas. Micro hydro can provide power for industrial, agricultural and domestic uses through direct mechanical power or by the coupling of the turbine to a generator to produce electricity. This paper deals with the potential of micro hydropower in India and the possibility of generating power in decentralized mode.

Introduction

The lack of energy supplies in rural areas is a chronic problem. In many developing countries less than 10 percent of the rural population has access to electricity. There are still 1.6 billion people in the world with no access to electricity, almost all of them living in developing countries (Anon., 2006). Rural electrification through conventional means such as grid connection or diesel generators is very costly. Water is a traditional source of power in many countries. The decentralized small-scale water power or micro-hydro schemes are a particularly attractive option in many rural areas.

For some years, interest in small hydropower went down drastically due to a number of factors: fast growth in electricity demand globally; progress of other technologies; success of large generation schemes and large grids in bringing down costs; mass production of small diesel sets that are both portable and easily installed; and easy access to affordable diesel fuel. In the more recent past, the energy crisis, climate change and energy poverty in developing countries has led to a rethink. Planners and policy makers are being urged to review all available energy options, especially those decentralized sources that could play a role supplying poor and isolated communities with energy for development.

History of Hydropower

The basic principle of hydropower is that if water can be piped from a certain level to a lower level, then the resulting water pressure can be used to do work. If the water pressure is allowed to move a mechanical component then that movement involves the conversion of the potential energy of the water into mechanical energy. Hydro turbines convert water pressure into mechanical shaft power, which can be used to drive an electricity generator, a grinding mill or some other useful device. The use of falling water as a source of energy has been known for a long time. Water wheels were used in ancient times, but the use of hydropower got a new impulse at the beginning of the nineteenth century with the invention of the hydro turbine.

Water wheels have been used since ancient times to supply power for grinding grain and other laborious tasks. The first modern hydraulic turbines were developed in the first part of the nineteenth century by Fourneyron in France. These were further developed by a number of researchers during the middle of the century, so that by 1890 most of the types of turbines now in use had been invented. Thomas Edison's invention of the electric light and ways to distribute electricity occurred at about the same time leading to a great boom in hydroelectric development in Europe and North America. Until about the 1920s, most hydroelectric developments were quite small in the size range, which is now called mini hydro or even micro hydro. This was for two reasons: people didn't know how to build really large dams and turbines, and the small electric transmission systems of the time made it difficult to sell large amounts of electricity. Generally, mini-hydro systems would be used to power a town and its surrounding area, while micro-hydro systems were used on isolated farms and ranches to provide power.

During the era of the 1950s and 1960s, advancing technology and cheap oil, combined with improved long-distance electric transmission made it possible to sell electricity cheaper than the earlier small hydro plants could make it. Small hydro is also well suited for developing countries, and is being actively encouraged by many governments and development organizations in order to reduce oil imports and encourage development. Micro hydro has a special role to play in developing countries, since it makes it possible to provide lighting, power, and communications (such as television and radio) even in areas far from the main electric power systems. Micro hydro can, thus, play an important role in promoting rural development in remote areas.

Features of Micro Hydro

The micro hydropower is one of the earliest known renewable energy sources, in existence in the country since the beginning of the 20th century. In fact, much before that, the technology was used in Himalayan villages in the form of waterwheels to provide motive power to run devices like grinders. References to mechanical energy extraction have been found from as early as twelfth century.

Micro hydro is usually defined as having a generating capacity of up to about 100 kW (Curtis, 1999). This is about enough power for 6 or 8 houses in a developed country, or it can provide basic lighting and other services to a village of 50 to 80 houses. Micro-hydro generation is best suited to providing small amounts of power to individual houses, farms, or small villages in isolated areas. Mini-hydro systems are larger, which is enough electric power for a medium-sized town. In general, micro-hydro plants use much simpler and lower cost technology than mini-hydro plants. For this reason, micro-hydro plants are usually well suited to village level development and local self-help projects. With their simpler technologies, they can usually be built by people with little special training, using mostly local materials and skills. They are usually lower in cost than mini-hydro and conventional hydro plants, but they are also less efficient, and the quality of the electricity is not as good. Mini-hydro plants, on the other hand, cost more, but they produce the same constant-frequency alternating current (AC) electricity as large electric power systems, so that they can even be interconnected with a larger system.

Micro-hydro plants generally produce low-voltage direct current (DC) electricity, or else low-voltage variable-frequency alternating current (AC). These kinds of electricity are suited for lights, small motors, and electric cookers, but not to run large motors, many appliances, or most industrial machinery. Perhaps, most importantly, micro-hydro plants cannot be interconnected with other generating plants in an electric system the way mini-hydro and large hydro plants can. Special machines called inverters can convert DC power to the AC power used in large electric systems, but these are expensive and have limited capacity.

The biggest advantage of micro hydropower is that it is the only 'clean' and renewable source of energy available round the clock. It is free from many issues and controversies that continue to 'hound' large hydro, like the submergence of forests, siltation of reservoirs, rehabilitation and relocation, and seismological threats. Other benefits of small hydro are user friendliness, low cost, and short gestation period. In addition to these obvious benefits, micro hydro contributes numerous economic benefits as well. It has served to enhance economic

Table 1 Definitions of small, mini, and micro hydro plants

Country	Micro hydro, kW	Mini hydro, kW	Small hydro, MW
India	< 100	101-1000	1-15
United States	< 100	100-1,000	1-30
China	-	< 500	0.5-25
Brazil	< 100	100-1,000	1-30
Norway	< 100	100-1,000	1-10
USSR	< 100	-	0.1-30
France	5-5,000	-	-
Various	< 100	< 1,000	< 10

Source: Moreire and Poole (1993)

development and living standards especially in remote areas with limited or no electricity. In some cases, rural dwellers have been able to manage the switch from firewood for cooking to electricity, thus, limiting deforestation and also cutting down on carbon emissions. On the macro level, rural communities have been able to attract new industries - mostly related to agriculture - owing to their ability to draw power from micro hydropower stations.

Hydropower is a very clean source of energy. It does not consume but only uses the water; after use it is available for other purposes. The conversion of the potential energy of water into mechanical energy is a technology with a high efficiency (in most cases double that of conventional thermal power stations). The use of hydropower can make a contribution to savings on exhaustible energy sources. Each 500 kWh of electricity generated with a hydro plant is equivalent to 100 litre of oil (assuming an efficiency of 38 percent).

World Potential

Hydropower technology has been extensively deployed throughout the world at both large and small scale for electricity generation, and at small scale for mechanical power. This generally places hydropower at an advantage over other renewable technologies for new deployment, since operational or abandoned schemes are often available within the target country. Operation, design and construction experience may also be available there. The technology is technically and commercially mature. Small scale hydro schemes can make a useful contribution to rural electrification strategies, presenting a suitable alternative to decentralized diesel generation, particularly where fuel supply is a problem. Some countries are encouraging deployment through subsidies and incentives.

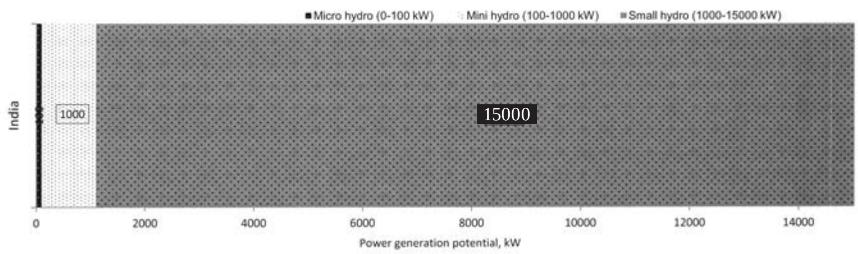
About 737 GW of hydropower with production 2,767 GWh/year has been developed globally, 47 GW/site of which is small hydropower. A total of about 118 GW of hydro capacity is under construction. The remaining non utilized global hydropower potential is estimated at 300 GW (Anon., 2004). About 82 percent of total technically feasible hydropower potential is exploited in USA, 73 percent in Germany, 65 percent in Canada, 23 percent in China, but only 5 percent in Africa and 13 percent in Asia as a whole (Anon., 2006).

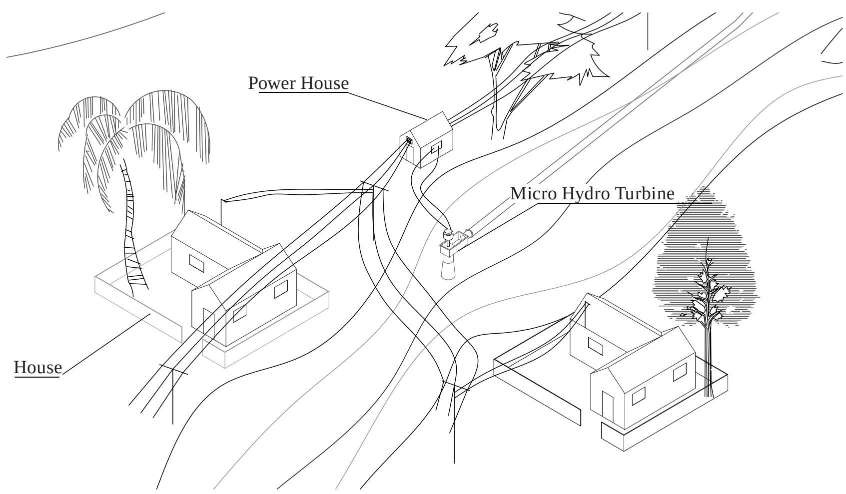
Indian Scenario

The Ministry of Power, Government of India is responsible for the development of large hydropower projects in the country, whereas Ministry of New and Renewable Energy (MNRE) has been responsible for small and mini hydro projects up to 3 MW station capacity since 1989. The subject of small hydro between 3-25 MW has been assigned to MNES from 1999. While there has been a continuous increase in the installed capacity of hydropower stations in India, which presently is 29,500 MW, the share of hydropower has been reduced to only 25 percent in the total installed for power generation from 50.62 percent in 1963 (Anon., 2005).

An estimated potential of about 15,000 MW of small hydropower projects exists in India (Anon., 2004). Ministry of New and Renewable Energy has created a database of potential sites of small hydro based on information from various states and on studies conducted by

Fig. 1 Hydropower categorization in India





the Central Electricity Authority. For projects up to 25 MW capacity, 4,096 potential sites with an aggregate capacity of 10,071 MW have been identified. Himachal Pradesh, Jammu Kashmir, Uttar Pradesh, Gujarat, Maharashtra, Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, Bihar, West Bengal and Arunachal Pradesh have been identified as key states with potential for small hydro.

Small hydropower technology was introduced in India shortly after the commissioning of the world's first hydroelectric installation at Appleton, USA in 1882. The 130 kW plant at Darjeeling in the year 1897 was the first small hydropower installation in the country. A few other power houses belonging to that period such as Shivasundaram in Mysore (2 MW, 1902), Galgoi in Mussoorie (3 MW, 1907), and Chaba (1.75 MW, 1914) and Jubbal (50 kW, 1930) near Shimla, are reported to be still functioning properly.

Performance of Micro Hydro

To determine the power potential of the water flowing in a river or stream it is necessary to determine both the flow rate of the water and the head through which the water can be made to fall. The flow rate is the quantity of water flowing past a point in a given time. Typical flow rate units are litres per second or cubic metres per second. The head is the vertical height, in metres, from the turbine up to the point where the water enters the intake pipe or penstock. The potential power can be calculated as follows:

$$P = 9.81 \times Q \times H$$

where, P is theoretical power in kW, Q is flow rate in m^3/s, H is head in m, and g is acceleration of gravity (9.81 m/s^2).

However, energy is always lost when it is converted from one form to another. Small water turbines rarely have efficiencies better than 80 percent. Power will also be lost in the pipe carrying the water to the turbine, due to frictional losses. By careful design, this loss can be reduced to only a small percentage. A rough guide used for small systems of a few kW rating is to take the overall efficiency as approximately 50 percent. Thus, the theoretical power must be multiplied by 0.5 for a more realistic Fig.

If a machine is operated under conditions other than full load or full flow then other significant inefficiencies must be considered. Part flow and part load characteristics of the equipment need to be known to assess the performance under these conditions. It is always preferable to run all equipment at the rated design flow and load conditions, but it is not always practical or possible where river flow fluctuates throughout the year or where daily load patterns vary considerably.

Depending on the end use requirements of the generated power, the output from the turbine shaft can be used directly as mechanical power or the turbine can be connected to an electrical generator to produce electricity. For many rural industrial applications shaft power is suitable (for food processing such as milling or oil extraction, sawmill, carpentry workshop, small scale mining equipment, etc.), but many applications require conversion to electrical power. For domestic applications electricity is preferred.

Components of Micro Hydro

There are many variations of micro-hydro systems. Some of the factors that will affect the kind of system to be built are: the amount of power needed; the quantity of flowing water available; the available head; the source of the water (from an irrigation canal, a pipeline, behind a dam, or from a free-flowing river or stream); affordable investment; and the manual skills and local materials available. All micro-hydro systems, whatever their other differences, have a number of features in common. Each must have a source of water, and a place to put the water afterwards (the discharge). The source must be higher than the discharge; the greater the difference in height, the greater the available head will be. In addition, there must be some means of getting the water from the source to the power plant, and then from the power plant to the discharge. Finally, there must be the power plant itself, which will contain one or more turbines driven by the flowing water, and one or more generators driven by the turbines. Alternatively, the turbines can supply mechanical power to drive some other machinery, such as a mill or saw, directly, without converting the mechanical power into electrical power and back. Sometimes, systems are arranged to supply mechanical power during the day, and then supply electricity for lighting at night.

a) Site and construction

The best geographical areas for exploiting small-scale hydropower are those where there are steep rivers flowing all year round, for example, the hill areas of countries with high year-round rainfall, or the great mountain ranges and their foothills, like the Himalayas. Islands with moist marine climates are also suitable. Low-head turbines have been developed for small-scale exploitation of rivers where there is a small head but sufficient flow to provide adequate power. To assess the suitability of a potential site, the hydrology of the site needs to be known and a site survey carried out, to determine actual flow and head data. This data gives a good overall picture of annual rain patterns and likely fluctuations in precipitation and, therefore, flow patterns. The site survey gives more detailed information of the site conditions to allow power calculation to be done and design work to begin. Flow data should be gathered over a period of at least one full year where possible, so as to ascertain the fluctuation in river flow over the various seasons.

The extent and the cost of the civil

works needed for a micro hydro plant vary a great deal, depending on the nature of the site where the plant is located. Generally, the more water-hydropower plants must handle, and the further they must carry it, the more expensive the civil works will be. For this reason, micro hydro plants with a lot of head are usually cheaper than low-head plants, since the lower head means a greater amount of water is required. However, many low-head plants can be built to take advantage of existing irrigation and water-supply works, such as dams and canals. Combining micro hydro with a water supply or irrigation project can also help to make that project more practical, since the power from the hydro plant can help to pay for some of the cost of the total project. The civil works can usually be built from local materials, using local construction techniques and labor, along with a few imported materials such as cement. The exception to this may be the penstock, which must be able to withstand the pressure of the water. If the head is more than 5 m, this will require metal pipe. This can be expensive, since a fairly large diameter pipe is required in order to reduce the amount of head lost from friction. If a dam should break, it can release water with great violence, and even a seemingly small amount of water can cause enormous destruction and loss of life.

Most hydro systems require a pipeline to feed water to the turbine. The exception is a propeller machine with an open intake. The water should pass first through a simple filter to block debris that may clog or damage the machine. The intake should be placed off to the side of the main water flow to protect it from the direct force of the water and debris during high flows. It is important to use a pipeline of sufficiently large diameter to minimize friction losses from the moving water. When possible, the pipeline should be buried. This stabilizes the pipe and prevents critters from chewing it. Pipelines are usually made from PVC or polyethylene although metal or concrete pipes can also be used.

b) Hydraulic turbine

Although traditional waterwheels of various types have been used for centuries, they are not usually suitable for generating electricity: They are heavy, large and turn at low speeds. They require complex gearing to reach speeds to run an electric generator. They also have icing problems in cold climates. Water turbines rotate at higher speeds, are lighter and more compact. Turbines are more appropriate for electricity generation and are usually more efficient.

There are two basic kinds of turbines: impulse and reaction. Impulse machines use a nozzle at the end of the pipeline that converts the water under pressure into a fast moving jet. This jet is then directed at the turbine wheel (also called the runner), which is designed to convert as much of the jet's kinetic energy as possible into shaft power. Common impulse turbines are pelton, turgo and cross-flow (Smith, 1994). In reaction turbines the energy of the water is converted from pressure to velocity within the guide vanes and the turbine wheel itself. Some lawn sprinklers are reaction turbines. They spin themselves around as a reaction to the action of the water squirting from the nozzles in the arms of the rotor. Examples of reaction turbines are propeller and Francis turbines.

In the family of impulse machines, the pelton is used for the lowest flows and highest heads. The cross-flow is used where flows are highest and heads are lowest. The turgo is used for intermediate conditions. Propeller (reaction) turbines can operate on as little as two feet of head. A turgo requires at least four feet and a pelton needs at least ten feet. These are only rough guidelines with overlap in applications. The cross-flow (impulse) turbine is the only machine that readily lends itself to user construction. They can be made in modular widths and variable nozzles can be used. Most developed sites now use impulse turbines. These turbines are very simple and relatively cheap. As the stream flow varies, water flow to the turbine can be easily controlled by changing nozzle sizes or by using adjustable nozzles. In contrast, most small reaction turbines cannot be adjusted to accommodate variable water flow. Those that are adjustable are very expensive because of the movable guide vanes and blades they require. If sufficient water is not available for full operation of a reaction machine, performance suffers greatly.

An advantage of reaction machines is that they can use the full head available at a site. An impulse turbine must be mounted above the tail-water level and the effective head is measured down to the nozzle level. For the reaction turbine, the full available head is measured between the two water levels while the turbine can be mounted well above the level of the exiting water. This is possible because the draft tube used with the machine recovers some of the pressure head after the water exits the turbine. This cone-shaped tube converts the velocity of the flowing water into pressure as it is decelerated by the draft tube's increasing cross section. This creates suction on the underside of the runner. Centrifugal pumps are sometimes used as practical substitutes for reaction turbines with good results. They can have high efficiency and are readily available (both new and used) at prices much lower than actual reaction turbines. However, it may be difficult to select the correct pump because data on its performance as a turbine are usually not available or are not straightforward. One reason more reaction turbines are not in use is the lack of available machines in small sizes.

c) Generator and electric gear

Most battery-based systems use an automotive alternator. If selected carefully, and rewound when appropriate, the alternator can achieve very good performance. A rheostat can be installed in the field circuit to maximize the output. Rewound alternators can be used even in the 100-200 V range. An induction motor with appropriate capacitance for excitation can be used as a generator, for higher voltages (100-400 V). This will operate in a small battery charging system as well as in larger AC direct systems of several kilowatts. Another type of generator used with micro hydro systems is the DC motor. Usually permanent magnet types are preferable. However, these have serious maintenance problems because the entire output passes through their carbon commutators and brushes.

The electrical gear or electrical system for a micro hydro system consists of the electric generator, other electrical devices in the powerhouse, and electric wires that take the electricity from the powerhouse to the place where it is to be used. There are a number of different possible arrangements for this. One of the most common arrangements for micro-hydro systems is a low-voltage DC system, similar to an automobile's electrical system. This arrangement can also be used to produce moderate-voltage AC power (like that which is available from an electric utility) by means of an inverter. Another arrangement, which is commonly used in mini hydro, is to generate moderate-voltage or high-voltage AC directly, using a synchronous generator.

d) Load control governors

The load factor is the amount of power used divided by the amount of power that is available if the turbine were to be used continuously. Unlike technologies relying on costly fuel sources the 'fuel' for hydropower generation is free and, therefore, the plant becomes more cost effective if run for a high percentage of the time. If the turbine is only used for domestic lighting in the evenings then the plant factor will be very low. If the turbine provides power for rural industry during the day, meets domestic demand during the evening, and maybe pumps water for irrigation in the evening, then the plant factor will be high. It is very important to ensure a high plant factor if the scheme is to be cost effective and this should be taken into account during the planning stage. Many schemes use a 'dump' load (in conjunction with an electronic load controller - see below), which is effectively a low priority energy demand that can accept surplus energy when excess is produced, e.g. water heating, storage heaters or storage cookers.

Water turbines, like petrol or diesel engines, will vary in speed as load is applied or relieved. Although not such a great problem with machinery, which uses direct shaft power, this speed variation will seriously affect both frequency and voltage output from a generator. Traditionally, complex hydraulic or mechanical speed governors altered flow as the load varied, but more recently an electronic load controller (ELC) has been developed which has increased the simplicity and reliability of modern micro hydro sets. The ELC prevents speed variations by continuously adding or subtracting an artificial load, so that in effect, the turbine is working permanently under full load. A further benefit is that the ELC has no moving parts, is very reliable and virtually maintenance free. The advent of electronic load control has allowed the introduction of simple and efficient, multi-jet turbines, no longer burdened by expensive hydraulic governors.

f) Power supply

Power can be supplied by a micro hydro system in two ways. In a battery-based system, power is generated at a level equal to the average demand and stored in batteries. Batteries can supply power as needed at levels much higher than that generated and during times of low demand, the excess can be stored. If enough energy is available from the water, an AC-direct system can generate power as alternating current (AC). This system typically requires a much higher power level than the battery-based system.

i) Battery based systems: Most home power systems are battery based. They require far less water than AC systems and are usually less expensive. Because the energy is stored in batteries, the generator can be shut down for servicing without interrupting the power delivered to the loads. Since only the average load needs to be generated in this type of system, the pipeline, turbine, generator and other components can be much smaller than those in an AC system. Very reliable inverters are available to convert DC battery power into AC output (120 volt, 60 Hz). These are used to power most or all home appliances. This makes it possible to have a system that is nearly indistinguishable from a house using utility power. The input voltage to the batteries in a battery-based system commonly ranges from 12 to 48 Volts DC. If the transmission distance is not great then 12 Volts is often high enough. A 24 Volt system is used if the power level or transmission distance is greater. If all of the loads are inverter powered, the battery voltage is independent of the inverter output voltage and voltages of 48 or 120 may be used to overcome long transmission distances. Although batteries and inverters can be specified for these voltages, it is common to convert the high voltage back down to 12 or 24 Volts (battery voltage) using transformers or solid state converters. Wind or solar power sources can assist in power production because batteries are used. Also, DC loads (appliances or lights designed for DC) can be operated directly from the batteries. DC versions of many appliances are available, although they often cost more and are harder to find, and in some cases, quality and performance vary.

ii) AC-direct systems: This is the system type used by utilities. It can also be used on a home power scale under the right conditions. In an AC system, there is no battery storage. This means that the generator must be capable of supplying the instantaneous demand, including the peak load. The most difficult load is the short-duration power surge drawn by an induction motor found in refrigerators, freezers, washing machines, some power tools and other appliances. Even though the running load of an induction motor may be only a few hundred watts, the starting load may be 3 to 7 times this level or several kilowatts. Since other appliances may also be operating at the same time, a minimum power level of 2 to 3 kW may be required for an AC system, depending on the nature of the loads. In a typical AC system, an electronic controller keeps voltage and frequency within certain limits. The hydro's output is monitored and any unused power is transferred to a shunt load, such as a hot water heater. The controller acts like an automatic dimmer switch that monitors the generator output frequency cycle by cycle and diverts power to the shunt load(s) in order to maintain a constant speed or load balance on the generator. There is almost always enough excess power from this type of system to heat domestic hot water and provide some, if not all, of a home's space heating.

Conclusion

Even though micro hydro has had an early start, the pace of growth in this sector has been very slow; vis--vis large hydro. This can be attributed to the rapid pace of industrialization after independence, which requires huge amounts of power and necessitates the installation of large multi-purpose power projects. However, with growing consciousness and concern about the environment, the focus has shifted towards the development of small, user friendly, and decentralized power projects with low gestation periods. Multi-faceted impetus is being provided by various agencies in the sector; for instance World Bank credit through the Indian Renewable Energy Development Agency and the Hilly Hydro Project funded by United Nations Development Programme-Global Environment Facility. The Ministry of New and Renewable Energy is offering, through its normal budget, a host of incentives for surveys, investigations, preparation of detailed project reports, and execution of projects. With these new and exciting developments, micro hydropower in India is poised to make a big splash.

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Multi-Purpose Solar Tunnel Dryer for a Mixed Farming System

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Abstract

The production of dried fish and preparation of value added products from low cost fish will have great prospects in near future. The solar dryer may be the best viable option for drying of fish. The results showed that fish attained a safe moisture limit in 18-28 hours in a solar tunnel dryer as compared to 34 hours in open sun drying. The average drying efficiency of the solar tunnel dryer was 18 percent higher than open sun drying. The solar tunnel dried fish was found of better organoleptic and keeping quality up to 3 months.

Introduction

The fisheries sector may be able to mitigate the protein deficiency in a developing country like India. The present per capita consumption of fish is 9.0 kg per annum in India against the desired level of 31 kg as recommended by the nutrition advisory committee on human nutrition and 11 kg as recommended by WHO. Food imports will not provide a complete solution to food security problems. Increase in productivity is the only real option. There is ample scope for improving supplies of fish for human consumption. The production of dried fish and preparation of value added products from low cost fish have great prospects in near future.

In the present context, the conventional methods of fish drying are open-sun drying on the floor, on black polythene sheet, on raised bamboo platform and hanging or tying on a rope. The conventional method of fish drying causes the loss of material and quality of the product and requires more time during the drying and, hence, reduces the cost of the final product. It is, therefore, necessary to dry the marine product in a closed chamber with controlled conditions. Various types of dryers have been developed and evaluated with varying performance results. In most of these studies, the advantages of an active system have not been fully exploited, primarily because of non-availability of electric power to operate the fan/blowers in rural areas. Active dryers have higher drying rates with faster drying enabling greater quantities of fish to be dried in a given time. Communities and cooperatives can pool their resources and acquire a power source for the fans used on these dryers. The solar dryer is the best viable option for drying fish with the abundantly available solar energy in the region. A study was undertaken to develop appropriate technology for fish drying during the non-monsoon season. The main objective of the study was to design, construct and evaluate the performance of a solar tunnel dryer.

Review of Literature

Bala and Mondol (2001) studied field level performance of the solar tunnel dryer with a transparent plastic covered flat plate collector and four d. c. fans operated by two 40 watt solar modules for drying of fish. The dryer could be used to dry up to 150 kg of fish. The temperature of the drying air at the collector outlet varied from 35.1 ºC to 52.2 ºC during drying. The salt treated fish was dried to a moisture content of 16.78 % (w.b.) from 67 % (w.b.) in 5 days of drying in a solar tunnel dryer as compared to 5 days of drying in the traditional method for comparable samples to a final moisture content of 32.84 %. The fish dried in the solar tunnel dryer was completely protected from rain, insects and dust, and was of better quality. Abedin *et al*. (2007) developed and constructed a solar tunnel dryer with a transparent foil covered flat plate collector, drying tunnel, two d. c. fans powered by a 40 watt solar cell module for drying fishes, vegetables and fruits. The air was heated by the collector and supplied into the drying tunnel. The moisture removal rate with the solar tunnel dryer and open sun drying was 120.96 gm/h and 65 gm/h, respectively, for drying jackfruit juice. Chavan *et al*. (2008) conducted a comparative study of a solar biomass, hybrid, cabinet dryer and an open-sun drying system for drying fish (variety: mackerel) to reduce moisture content from 72.50 ± 0.44 % (w.b.) to 16.67 ± 0.52 % (w.b.) in a solar bio-mass hybrid cabinet dryer and 16.92 ± 0.54 % (w.b.) in the open sun drying system.

Materials and Methods

Dryer Design Analysis

Angle of declination, δ

$$\delta = 23.46 \sin [0.9863 \{\sin (284 + n)\}] \quad (1)$$

Optimum collector slope, β

$$\beta = \delta + Ø \quad (2)$$

Angle of incidence of radiation on the horizontal surface, θ_h

$$\theta_h = \sin \delta \times \sin Ø + \cos \delta \times \cos Ø \times \cos \omega \quad (3)$$

Angle of incidence of radiation on the collector surface, θ

$$\cos \theta = \sin \delta \times \sin Ø + \cos \beta - \sin \delta \times \cos Ø \times \sin \beta \times \cos \gamma + \cos \delta \times \cos Ø \times \cos \beta \times \cos \omega + \cos \delta \times \sin \beta \times \sin Ø \times \cos \gamma \times \cos \omega + \cos \delta \times \sin \beta \times \sin \gamma \times \sin \omega \quad (4)$$

Insolation on the collector surface, I_s

$$I_s = I_h \cos \theta / \cos \theta_h \quad (5)$$

Where,

n = day of year;

δ = angle of declination (degree);

Ø = latitude of location;

ω = hour angle;

γ = surface azimuth angle for the dryer;

β = Optimum collector slope

θ_h = Angle of incidence of radiation on horizontal surface

θ = Angle of incidence of radiation on collector surface

I_h = Insolation on horizontal surface (kJ/m^2).

I_s = Insolation on collector surface

The initial drying conditions for design of solar tunnel dryer are shown in **Table 1** while parameters of drying air are predicted using psychrometric chart (**Table 2**).

The following design parameters were considered for the design of the natural convection solar tunnel drying system

Total weight of water in fish,

$$W_{tw} = W_g \times M_i / 100 \quad (6)$$

Bone dry weight of fish,

$$W_{bd} = W_g \times \{1 - (M_i / 100)\} \quad (7)$$

Amount of moisture to be removed for safe storage, Ww (kg),

$$W_w = W_g \times (M_i - M_f) / (100 - M_f) \quad (8)$$

Average drying rate in kg/h,

$$W_{dr} = W_w / t_d \quad (9)$$

Useful heat energy required, E_u (kJ)

i) *Sensible heat of fish* $= W_{bd} \times C_{fish} \times \Delta T$ (10)

ii) *Sensible heat of water* $= W_{tw} \times C_w \times \Delta T$ (11)

iii) Latent heat of water vapour $= Ww \times \lambda$ (12)

iv) Total heat required,

$$E_u = (i + ii + iii) + \{(i + ii + iii) \times heat_{loss}\}$$

The quantity of air required for drying in m^3,

$$Q_a = E_u / \{C_a \times p_a (T_e - T_a)\} \quad (13)$$

Volume flow rate of air required in m^3/h,

$$Q_{vol} = Q_a / t_d \quad (14)$$

Total collector area in m^2,

$$A_c = E_u / (I \times \eta) \quad (15)$$

Where,

W_g = Weight of fish for drying, kg;

M_i = Initial moisture content of

Table 1 Initial conditions for design of the solar tunnel dryer for fish

Type of Material	Prawns	Latitude	17º45′
Location	Dapoli	Longitude	73º26′
Ambient Temperature, T_a	25 ºC	Wind velocity	3.9 m/s
Ambient Relative Humidity, RH_a	70 %	Average Sunshine Hrs.	8.5 hrs.
Specific Heat of Air, C_a	1.01 kJ/kg ºC	Weight of Material, W_a	100 kg
Initial Moisture Content, M_i	77.4 %	Drying temp of fish	50 ºC
Final Moisture Content, M_f	16 %	Exhaust air temperature, T_e	33.5 ºC
Drying Period	9:00-17:00	Density of exit air, ρ_e	1.0539 kg/m^3
Efficiency of dryer, η	30 %	Density of fish, ρ_{fish}	335 kg/m^3
Specific heat of water, C_w	1.0 kcal/kgºK	Solar insolation, I	300 kcal/m^2
Latent heat of vaporization, λ	2,383 kJ/kg	Specific heat of fish, C_{fish}	0.70 kcal/kgºK
Air density at amb. temp., ρ_a	1.115 kg/m^3	Density of air at 0 ºC, ρ_0	1.252 kg/m^3

Table 2 Predicted drying air using a psychrometric chart

Properties	Ambient air	Drying air	Exit air
Temperature, ºC	25	50	33.5
Relative Humidity, %	70	14	70
Specific Volume, m^3/kg	0.865	0.95	0.905
Humidity ratio, kg/kg of air	0.014	0.014	0.0245
Enthalpy, kcal/kg	14.5	22.3	22.3

fish, % w.b.;

M_f = Final moisture content of the fish, % w. b.;

m_f = Bone dry weight of fish, kg;

t_d = Drying time required for removing W_w kg of water from wet raw fish, hours;

E_u = Total useful heat energy required to evaporate moisture from the fish, kcal;

C_{fish} = Specific heat of fish, kcal/kg^{0}K;

C_w = Specific heat of water, kcal/kg^{0}K;

C_a = Specific heat of air at constant pressure, (kJ/kg- ºC);

ρ_a = Density of drying air, kg/m^3;

$heat_{loss}$ = 35 %;

ΔT = Temperature difference between drying air and exhaust air, ºC;

T_a = Initial temperature of the drying air, ºC;

T_e = Final temperature of the drying air, ºC;

I = Total global radiation on horizontal surface during the drying period, kcal/m^2;

η = Collector efficiency, 30 % to 50 % (Basunia and Abe, 2001).

Dryer dimensions

$Area = D \times L$ .... (16)

Number of trays

(a) Volume of fish dried,

$V_{fish} = W_g / P_{fish}$ .... (17)

(c) Drying area = V_{fish} / T_{fish},

where thickness of fish,

$T_{fish} = 0.01\ m$ .... (18)

For loading and unloading of prawns, three trolleys were provided each with two trays of surface area 5 m^2.

Dimensions of chimney

Since airflow rate in the dryer takes place due to the draft caused by the pressure difference between outside cold air and inside hot air, the diameters and height of chimney are determined as follows.

$D_1 = H \times g \times (p_i - p_e)$ .... (19)

Actual draft was assumed to be 75 % of this draft (P).

a) Actual draft,

$D_2 = 0.75 \times D_1$..................... (20)

b) Velocity of exit air,

$V_e = \sqrt{(2D_2 / p_e)}$ .... (21)

c) Volume of exit air,

$Vole = Q_a / P_e$ .... (22)

d) Rate of exit air,

$Q_e = Vol_e / t_d$ .... (23)

e) Cross sectional area of chimney,

$a_c = Q_e / V_e$........................... (24)

f) Diameter of chimney,

$D_{chimney} = \sqrt{4a_c / \pi}$................. (25)

(M) Dimensions of north wall

i) Total area of polythene as covering material,

$A_{cover} = (\pi \times D \times L) / 2$ .... (26)

ii) Perimeter of solar tunnel dryer,

$P = (\pi \times D) / 2$ .... (27)

Since the perimeter (P) covers diametrical length, Lp = 4.0 m and since 32 % of this area is to be protected (Kumar *et al*., 2006).

iii) For example the area for protecting the north wall is

$A_p = 0.32 \times A_{cover}$ .... (28)

iv) Arc width of cover for energy losses,

$w = A_p / L$ .... (29)

v) Arc width (w) will cover diametrical length,

$L_{pi} = (L_p \times w) / p$ .... (30)

vi) Height of north wall,

$h_{nw} = \sqrt{(w^2 - L_{pi}^2)}$..................(31)

where,

Area = collector area A_c, m^2;

D = diameter i.e. width of dryer, m = 3.75 m;

L = length of dryer, m;

D_1 = Pressure difference between outside air and inside air, Pa;

g = Acceleration due to gravity 9.81 m/s^2;

H = Height of the chimney, m;

ρ_{fish} = Density of fish, kg/m^3;

ρ_i = Inlet air density, kg/m^3;

ρ_e = Exit air density, kg/m^3;

t_d = Drying time, hr;

A_{cover} = area of polythene covering material, m^2;

A_p = Area of protecting north wall, m^2;

D = Diameter of tunnel, m;

L = Length of tunnel, m;

P = Perimeter of solar tunnel dryer, m;

w = Arc width (w) will cover diametrical length, m;

L_{pi} = Arc width of cover through which energy losses, m;

H_{nw} = Height of north wall, m

Description and Construction of Dryer

The present study was undertaken at the Department of Electrical and

Fig. 1a Isometric view of solar tunnel dryer (100 kg/batch)

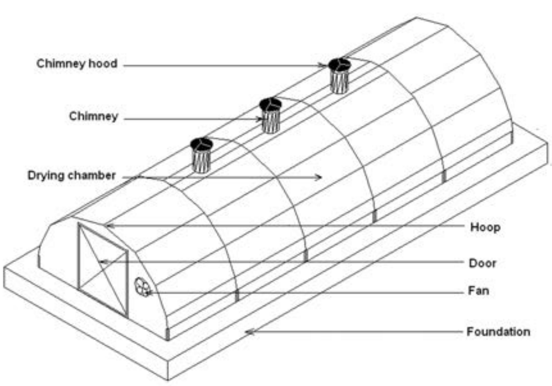


Fig. 1b Isometric view of solar tunnel dryer (100 kg/batch)

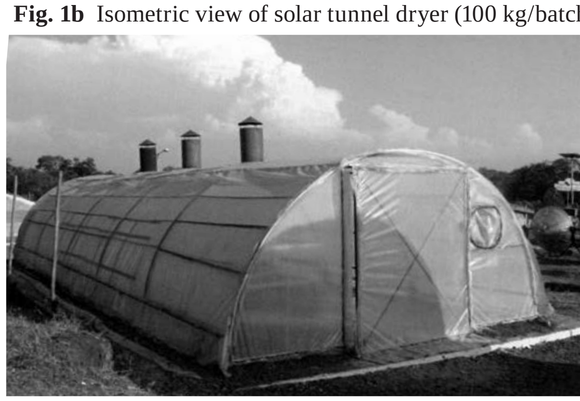


Table 3 Technical specifications of solar tunnel dryer for fish (100 kg/ batch)

Particulars	Specifications	Material
Collector Area, sq. m	37.5 (3.75 m width × 10 m length)	--
Drying tray area, sq. m	2.5 (1.6 m × 1.6 m)	Al. wire mesh
Number of trays	04 on each trolley	MS angle
Number of trolleys	3 Nos., width 1.67 m, Length 3.12 m	----
Height of tunnel, m	2.0	--
Chimney, m	3 Nos., Ø 0.30 m, Length 0.50 m	20 SWG MS
Fresh air vent area, sq. m	0.05	--
Exhaust Fan, single phase	2 Nos, Brushless AC, 410 Wp, 1400 rpm	---
Door	1.75 m × 1.75 m	MS angle
North wall	Height 1.55 m, Length 10 m	GI sheet

Table 4 Experimental and treatment details for drying tiny prawns

a) Peeling:	Two	b) Salting:	Two	c) Tray location:	Three
	F_1-Whole		S_0-Unsalted		L_1-Upper
	F_2-Peeled		S_1-Salted		L_2-Lower
d) Repli-cations:	Three				L_3-Open

Other Energy Sources, College of Agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, Maharashtra State (India) during the year 2008-09. The solar tunnel dryer consisted of a cover of U.V. stabilized polyethylene sheet (200 μm) fixed on cladding material with the help of zigzag springs. The floor of the solar tunnel dryer was constructed with cement concrete and painted black for absorbing solar radiation to increase the inside dryer temperature. The supports for chimney, door and exhaust fan were welded. The north wall was placed at north side of solar tunnel dryer to minimize energy loss. The technical specifications and isometric view of solar tunnel dryer are presented in **Table 3** and **Fig. 1**. The pictorial view of solar tunnel dryer is given in **Fig. 2**.

Evaluation of the Dryer

The performance of the solar tunnel dryer was evaluated under actual conditions. Fish samples with known moisture content were loaded on trolleys over trays in the dryer as per predetermined salting and cutting treatment. Variation in temperature and relative humidity was measured at 1 hour intervals at the centre of the solar tunnel dryer along with ambient conditions. Initial and final moisture content of the fish were measured by the oven drying method. Drying was continued till the moisture content of the fish samples attained safe moisture content, i.e. 16 % w.b. (Ali and Agarwal, 1980). The experimental and treatment details for drying of tiny prawns are given in **Table 4**.

The moisture content, moisture ratio and drying efficiency were determined by

$$M.C.\ (d.b.)\ \% = (W_1 - W_2) / W_2 \times 100 \quad \ldots\ldots (32)$$

$$Moisture\ Ratio\ (M.R.) = (M - M_e) / (M_0 - M_e) \quad \ldots\ldots (33)$$

$$\eta_d = (W_i \times C_f \times \Delta T) + (W_w \times C_w \times \Delta T) + (W_w \times \lambda) / (I \times A_c \times N) \quad \ldots\ldots (34)$$

where,

W_1 = Weight of sample before drying (g),

W_2 = Weight of bone dried sample (g),

M = Moisture content (percent d. b.),

M_e = EMC (percent d. b.),

M_0 = IMC(percent d. b.),

W_i = Initial weight of material (kg),

C_f = Specific heat of fish (0.70 kcal/kg°k),

ΔT = Temperature rise,

W_w = mass of water evaporated (kg),

C_w = specific heat of water (1 kcal/kg°k),

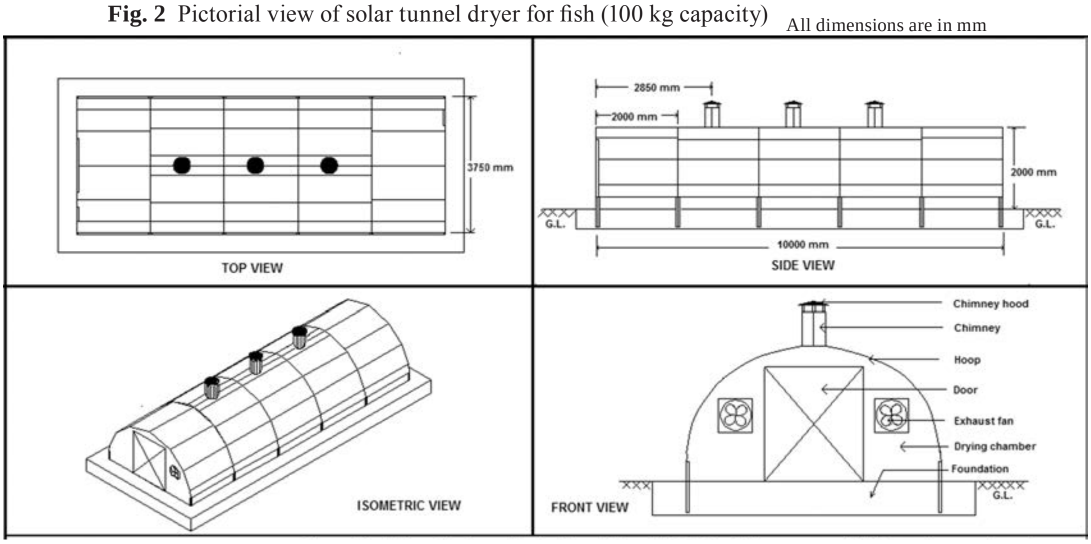
λ = Latent heat of vapourization (540 kcal/kg),

I = incident solar radiation on collector (kcal/m^2-h),

A_c = drying area (80 % of collector area) and

N = drying hours (h).

Fig. 2 Pictorial view of solar tunnel dryer for fish (100 kg capacity) All dimensions are in mm



Results and Discussion

The no-load performance trials were carried out for the solar tunnel dryer at the site during the winter (October to December) and summer (February to April) season for testing of design parameters (**Fig. 3** to **Fig. 6**).

The average rise in temperature inside the solar tunnel dryer was 11.24 ºC and 18.29 ºC over the ambient temperature during no-load test in winter and summer, respectively. The maximum average temperature inside the solar tunnel dryer during winter and summer no-load test was 52.41 and 65.69 ºC at the centre of solar tunnel dryer followed by north side (51.06 and 64.94 ºC) and south side (47.69 and 63.48 ºC), respectively. The increased temperature and decreased relative humidity at the centre side could be attributed to maximum direct radiations reaching the absorber surface and consequent temperature rise in solar tunnel dryer by convection heat transfer to air inside the dryer. The lower temperature and increased relative humidity at south could be attributed to incoming air through air inlets provided at south of solar tunnel dryer.

Full load testing of the dryer was carried out by loading whole and peeled tiny prawns (Parapaeneopsis stylifera) with salting (10 % concentration salt for one hr) and without salting. The variation in temperature, relative humidity and solar radiation during full load testing inside the solar tunnel dryer are shown in **Fig. 7**. During full load testing, the average rise in temperature of drying air was 14.43 ºC over the ambient temperature, whereas, the relative humidity varied inside the dryer and was about 31.28 to 49.95 % as against the ambient relative humidity of 23.1 to 52.57 %.

The temperature inside solar tunnel dryer at the upper tray and lower tray was 60.99 ºC and 56.09 ºC, respectively, at 13:00 h with average relative humidity of 31.45 %. The corresponding ambient temperature, relative humidity and solar intensity were 33.24 ºC, 33.66 % and 630.94 w/m^2, respectively. The average temperature and relative humidity inside the solar tunnel dryer were 45.14 ºC and 39.22 %, respectively while average ambient temperature and relative humidity were 30.71 ºC and 36.90 %, respectively.

Open-Sun Drying

Drying curves showed a relatively

Fig. 3 Variation in temperature inside the solar tunnel dryer during winter for no-load test

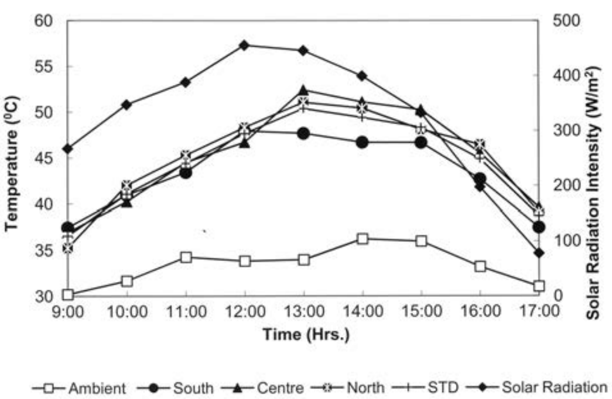


Fig. 4 Variation in RH inside the solar tunnel dryer during winter for no-load test

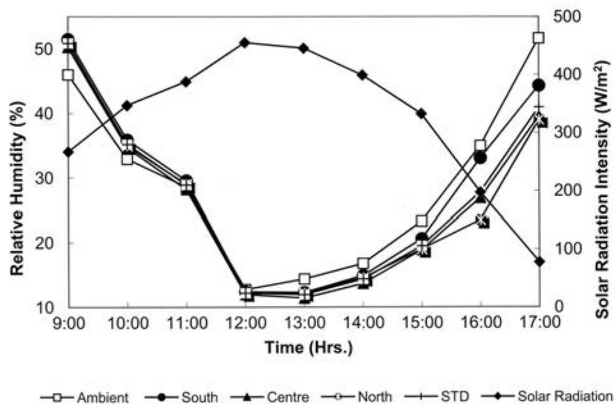


Fig. 5 Variation in temperature inside the solar tunnel dryer during summer for no-load test

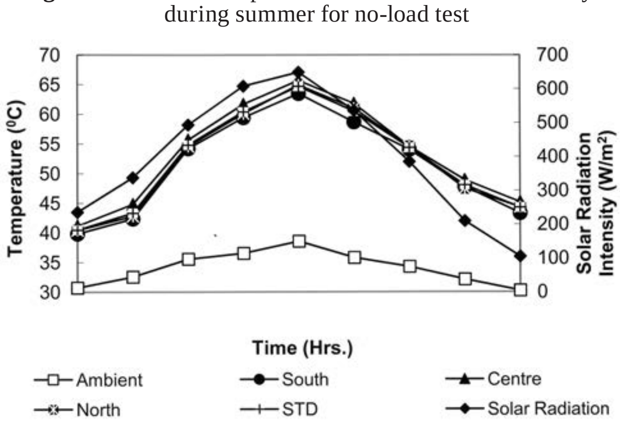
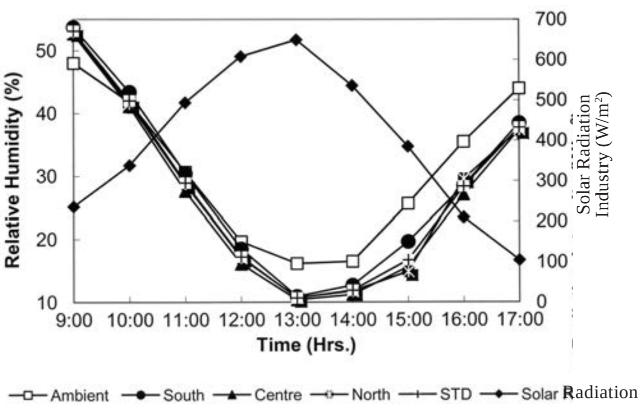
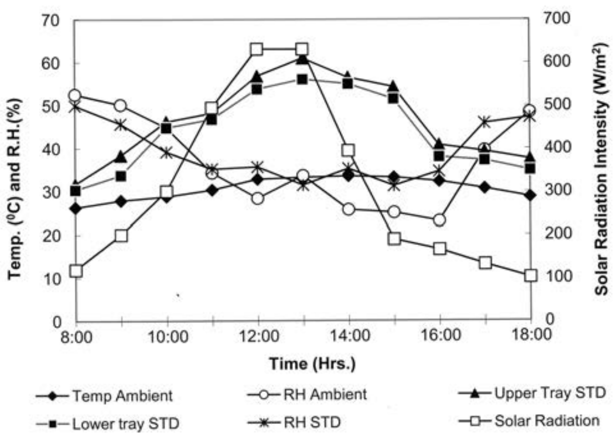


Fig. 6 Variation in RH inside the solar tunnel dryer during summer for no-load test



rapid decline in moisture content during initial stages and subsequent slowing down of the drying process. For whole fish drying, the sudden fall in moisture content after four to five hours in the morning was due to hastening of moisture migration from the fish body. The drying rate was enhanced due to favourable environmental conditions. The drying curve with respect to drying time for drying of whole and peeled tiny prawns in open-sun drying are shown in **Figs. 8** and **9**. The drying time required for salted whole, unsalted whole, salted peeled and unsalted peeled tiny prawns from 344.86 % d. b. to about 19 % d. b. required 30, 34, 30 and 34 hrs, respectively, in open-sun drying. The average moisture ratio for drying of salted whole, unsalted whole, salted peeled and unsalted peeled tiny prawns in open-sun drying was 0.28, 0.34, 0.36 and 0.39, respectively.

Fig. 7 Variation in temperature and relative humidity inside the solar tunnel dryer during load test



Solar Tunnel Dryer

The variation in moisture content and moisture ratio with respect to drying time for drying of whole and peeled tiny prawns in solar tunnel dryer at upper and lower tray position are shown in **Figs. 10** and **11**.

The drying time required for salted prawns from initial moisture content of 344.86 % d.b. to about 19 % d.b. was 32 hrs in open sun drying method. The drying time for salted whole, unsalted whole, salted peeled and unsalted peeled tiny prawns from 344.86 % d. b. to

Fig. 8 Moisture Content Vs Drying Time for Tiny Prawns in Open Sun Drying

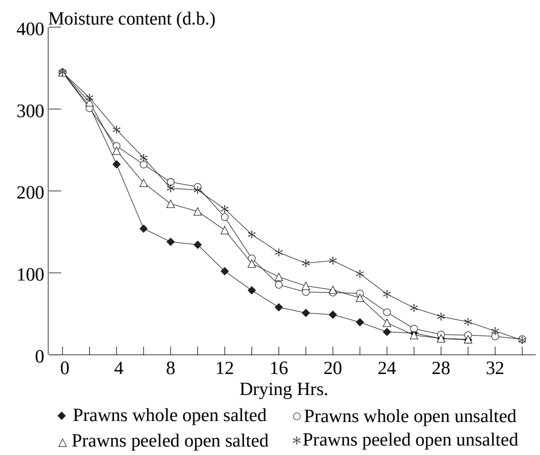


Fig. 9 Moisture Ratio Vs Drying Time for Tiny Prawns in Open Sun Drying

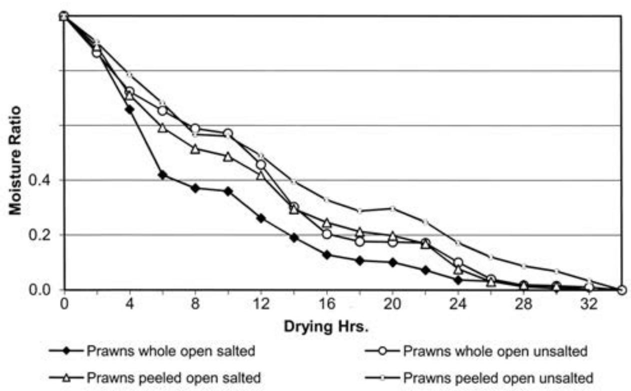


Fig. 10 Moisture content vs drying time for tiny prawns in solar tunnel dryer

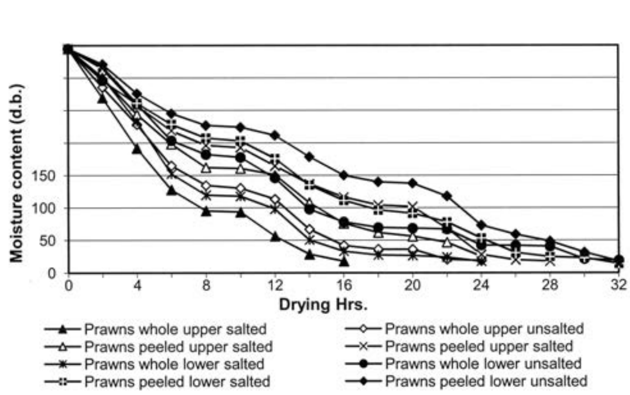
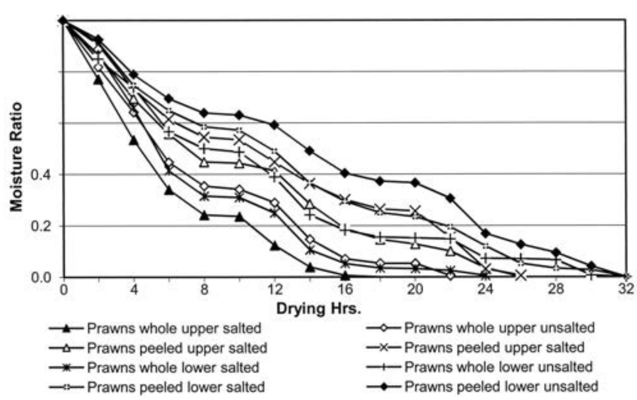


Fig. 11 Moisture ratio vs drying time for tiny prawns in solar tunnel dryer



about 19 % d. b. required 18, 24, 26 and 28 hrs, respectively, at upper tray of solar tunnel dryer. Whereas, for drying of salted whole, unsalted whole, salted peeled and unsalted peeled tiny prawns from 344.86, % d. b. to about 19, % d.b. required 26, 32, 32 and 32 hrs, respectively, at lower tray of the solar tunnel dryer. The average moisture ratio for drying of salted and unsalted whole tiny prawns was 0.36 and 0.35, respectively, for the upper tray and 0.33 and 0.33, respectively, for the lower tray. Drying of salted and unsalted peeled tiny prawns for the upper tray was 0.40 and 0.44, respectively, and 0.40 and 0.45, respectively, for the lower tray inside the solar tunnel dryer.

The drying efficiency for unsalted whole tiny prawns and unsalted peeled tiny prawns was 19.29 and 16.59 %, respectively, and the drying efficiency open-sun dried unsalted whole tiny prawns and unsalted peeled tiny prawns was 15.55 and 15.61 %, respectively, as shown in **Fig. 12**. The drying efficiency of solar tunnel dried salted whole tiny prawns and salted peeled tiny prawns was 27.66 and 20.41 %, respectively, whereas that for open-sun dried salted whole tiny prawns and salted peeled tiny prawns was 17.67 and 17.63 %, respectively, as shown in **Fig. 13**.

Drying efficiency was significantly higher for salted fish over unsalted. This may have been due to binding of water molecules with salt (osmosis). The drying efficiency of whole tiny prawns was, comparatively, more than that for peeled tiny prawns in, which may have been due to moisture uptake during the pre-processing of peeled tiny prawns as compared to whole tiny prawns. In organoleptic analysis, the overall acceptability of solar tunnel dried whole tiny prawns (28.5) was higher followed by solar tunnel dried peeled tiny prawns (56.5). The open sun dried whole and peeled tiny prawns (95.5 and 120) were least accepted.

Conclusion

The solar tunnel dryer leads to faster drying of fish with an average drying efficiency of about 18 % higher than the open sun dried fish. The solar tunnel dried fish was of better organoleptic and keeping quality up to 3 months.

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Fig. 12 Drying efficiency of salted prawns

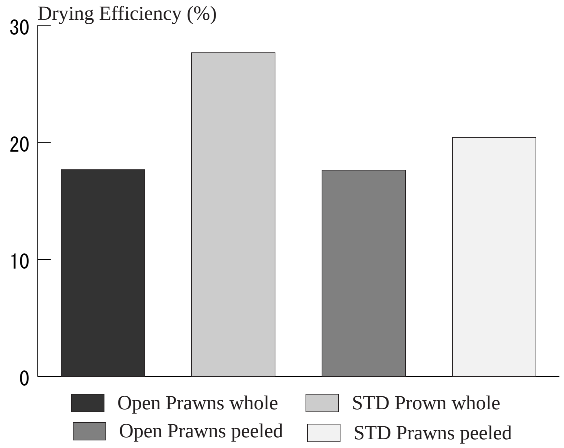
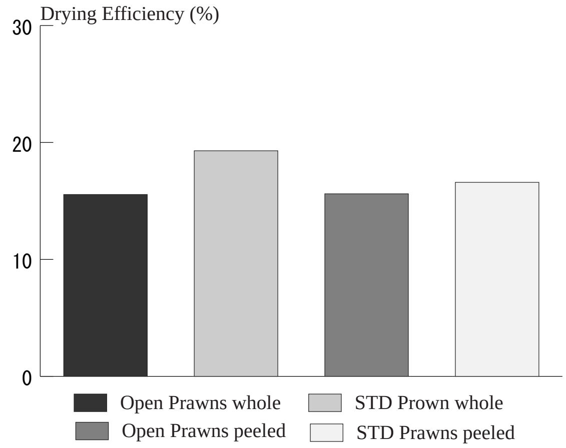


Fig. 13 Drying efficiency of unsalted prawns



Energy Consumption Pattern in Production of Paddy Crop in Haryana State in India

by

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Abstract

Energy in agriculture is a mover and sustainer of crop production and agro-processing for value addition. On- farm energy use pattern in paddy crop systems, both source wise and operation wise, was determined to prepare an energy audit in crop production systems. The data on energy consumption from different sources for production of paddy was collected from Haryana state. Energy consumption was cotegorised with respect to, animate and inanimate sources, direct and indirect, commercial and noncommercial, renewable and non renewable farm holdings of the farmers. The results revealed that the consumption of energy in paddy cultivation by small, medium and large category farmers were 32,417.7, 36,471.61, and 36,742.85 MJ/ha, respectively. The consumption of direct sources and indirect sources of energy was 60 % and 40 %, respectively while in terms of renewable and non renewable sources of energy, the observed consumption was 8 and 92 %, respectively. It was further observed that energy through electric energy consumption was more in all the operations as well as in all size of farm holdings.

Introduction

India is a predominantly agricultural country. About 70 % of its population depends on agriculture. Wheat and rice are the two major cereal crops that occupy about 50-55 % of the total cropped area of India. Paddy alone covers about 40-45 % of the total area covered by cereal crops. Paddy production is a direct function of high yielding varieties, chemicals, fertilizers, mechanization and other energy inputs. Technology level, energy input and agro-climatic zone constitute the most pertinent set of factors responsible for the higher production of paddy. Paddy is produced using energy sources ranging from human and animal power to power of heavy machinery. Energy input and yield vary with use of different sources of energy, influencing the ultimate output–input ratio. For efficient and precise use of energy, analysis of energy in crop production system is a must. Research workers have been using it as an effective management tool for analyzing the crop production in relation to energy inputs (Baruah *et al.*, 2004; Vredeveld *et al.*, 1983; Zentner *et al.*, 2004; and Zoobel, 2000). Assessment and evaluation of alternative management practices followed by better management resulted in more efficient energy utilization in crop production. The present study was undertaken to estimate and compare the energy requirements for the production of paddy crop in selected paddy growing areas of Northern India with respect to technology level, energy input and agro-climatic zones.

Methodology

The study area included villages of parts Karnal and Jajjhar districts of Haryana. The selection of villages took into consideration the spatial variability along with cropping pattern, socio-economic considerations, irrigation facility, cultural practices and energy use levels. A proforma was devised in order to collect required information related to land holdings, cultural practices in paddy production, time of operation, fuel consumption, and electricity consumption in different operations along with consumption of seed, fertilizer, chemicals. The information was helpful in estimation/assessment of energy use in production of paddy. The data were collected by making personal contact with the individual farmer. The data on inventory of all the farm machines like hand tools, tractor and power operated implements and rural transport devices/vehicles available with different categories of farmers were taken.

The energy use values were determined by multiplying the associated energy equivalents/coefficients (Mittal *et al*., 1985). Total output energy was determined based on the energy value associated with paddy grain (14.7 MJ/kg dry grain) and energy associated with the paddy straw (13.75MJ/kg dry straw). Further, the ratio of output-input energy was calculated based on the use of both direct and indirect energies in the production process and yield of grain and straw.

Estimation of Energy Input in Different Size of Farms

The farms were classified on the basis of cultivable land available with farmers. The following classification was used in accordance with the classification used by the Indian Council of Agricultural Research (ICAR) (Mittal *et al*., 1985). In this paper only small, medium and large farms were considered.

Estimation of Energy Input In Different Modes of Energy Sources

The mode wise energy sources used in paddy production were calculated using the following criteria:

Direct energy	Human, animal, petrol, diesel, electricity, irrigation water from canal
Indirect energy	Seeds, fertilizers, farmyard manure, chemicals, machinery
Renewable energy	Human, animal, seeds, farmyard manure, canal
Non-renewable energy	Petrol, diesel, electricity, chemicals, fertilizers, machinery
Commercial energy	Petrol, diesel, electricity, chemicals, fertilizers, seeds, machinery
Non-commercial energy	Human, animal, farmyard manure, canal

Results and Discussion

Pattern of Energy Use —Source Wise

In agricultural production processes, both direct and indirect forms of energy are needed. The direct energy for this study included both animate and inanimate energy. During the last couple of decades animal energy use in agriculture has reduced drastically. As a result animate energy component included human energy only, which was required in all the unit operations of crop production including those that are done using mechanical or electrical energy.

As stated earlier, paddy is the main crop of the northern Indo-genetic plain of India. A lot of efforts have been made into research on different aspects of paddy cultivation during and after the green revolution period. With the application of advanced technologies energy consumption in paddy production has increased over the years. The electrical energy consumption by different categories of farmers in cultivation of paddy was maximum, followed by fertilizer, diesel, human, chemical, animal, seed and machinery energy. The average electrical energy consumption by small, medium and large category farmers was 11,920.14, 15,312.53 and 17,465.82 MJ/ha, respectively, in that order (**Table 1**). The irrigation was mainly done by electric driven pumps. Hence, maximum electrical energy was used. The electrical energy consumption showed a visible variation among different categories of farmers. The small, medium and large category farmers consumed almost equal amount of fertilizer energy (**Table 1**). The contribution of mechanical energy was relatively lower for the paddy crop. The paddy crop did not require either more tillage or seeding by tractor machinery. In comparison to other crops human energy consumption in paddy crops was more; 1,954.07, 1,986.84, 2,173.73 MJ/ha for small, medium and large category farms, respectively, in that order. The chemical energy contribution in paddy cultivation was 1.74 % whereas contribution from seed energy was 0.79 %. Farmers of the area followed recommended seed rate of 7-9 kg/acre in paddy crop, which helped in reducing requirement of seed energy. The average chemical energy consumption in paddy was 600 MJ/ha and, category wise, all categories of farmers consumed equal amounts of chemical energy. The energy consumption showed variation with respect to holding sizes only in the case of electrical energy as the farmers used varying amounts of irrigation. It was a hard fact that Karnal farmers were using 20-26 irritations in paddy crop. Other sources of energy patterns of consumption did not show any visible variation with land holding pattern. The total energy consumption by small, medium and large category farmers was 32,417.67, 36,471.61 and 36,742.85 MJ/ha, respectively.

To study the influence of land holdings on energy consumption, an analysis of variance was performed. The analysis of variance showed significant difference for mechanical, seed and fertilizer energy at the 5 % level. This was due to relatively large variation in use of electrical, mechanical and fertilizer energy.

Energy Consumption under Different Modes of Energy Sources for Cultivating Paddy Crop

The total mean energy input

Table 1 Source wise average energy (MJ/ha) consumption

Particulars	Size of farm		
	Small	Medium	Large
A. Input			
Human	1,954.07	1,986.84	2,173.73
Animal	643.23	459.45	304.19
Diesel	3,545.78	4,037.89	3,288.51
Electrical	11,920.14	15,312.53	17,465.82
Seed	295.17	281.75	242.55
Fertilizer	13,326.38	13,616.75	12,455.25
Chemical	600.00	600.00	600.00
Machinery	132.9	176.4	212.8
Total Energy Input	32,417.17	36,471.61	36,742.85
B. Output			
Yield (kg/ha)	7,100	6916	5,767
Yield energy output (MJ/ha)	104,370	101,665	88,775
Straw output (kg/ha)	5,500	5,250	4,563
Straw energy output	68,750	65,625	57,038
Total energy output	173,120	167,290	14,5813
C. Others			
Energy ratio	5.36	4.61	3.99
Specific energy (MJ/kg)	4.55	5.25	6.33
Energy productivity (kg/MJ)	0.22	0.19	0.16
Net Energy yield	140,835.2	130,994.8	109,282.9

Table 2 Mode wise energy (MJ/ha) consumption

Modes of energy	Paddy
Direct	21,030.73 (59.7)*
Indirect	14,179.98 (40.3)
Renewable	2,780.33 (7.9)
Non-renewable	3,2430.38 (92.1)
Commercial	3,2703.54 (92.9)
Non-commercial	2,507.17 (7.1)

*Fig. in parenthesis represents percent

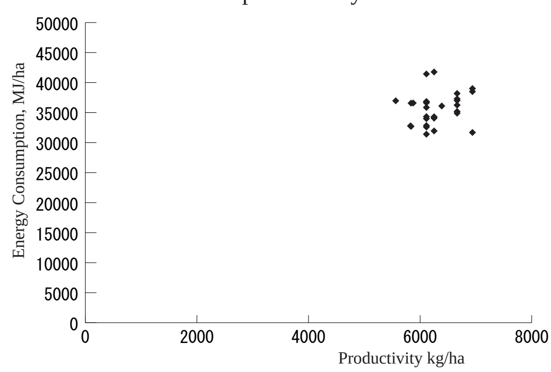
along with its direct and indirect, renewable and non-renewable and commercial and non-commercial forms for raising paddy crop is presented in **Table 2**. The direct energy (21,030.73 MJ/ha) input is higher in paddy crop compared to indirect energy (14,179.98 MJ/ha). On an average, the direct energy input remained at 59.7 % of the total energy input compared to 40.3 % indirect energy. The energy use is more in irrigation, which is samilar to the pattern of (Singh and Singh, 1976). There was more consumption of non-renewable energy input (92.1 %) than renewable form (7.9 %), **Table 2**. Consumption of both renewable and non-renewable forms of energy varied with location. The reduction in consumption of nonrenewable energy has a direct bearing on the cost of cultivation. The component of non-renewable energy is high in all the villages. The maximum use of nonrenewable energy input indicated more use of diesel, electricity, fertilizer, machines, etc. There was more consumption of commercial forms of energy input (on an average 92.9 %) than non-commercial form (7.1 %) (**Table 2**). Similarly, the commercial and non-commercial forms of energy inputs also varied with locations. The reduction in consumption of commercial energy has a direct bearing on the cost of cultivation.

The component of commercial energy was high in all the villages. The maximum commercial energy input, which contributed to enhanced use of diesel, electricity, fertilizers and machineries as compared to human, animal and farmyard manure. The total energy output was highest (140,835.2 MJ/ha) for small farmers followed by medium (130,994.8 MJ/ha) and large farmers (109,282.9 MJ/ha), respectively, **Table 1**. But, energy ratio was lowest (3.99) for large farmers followed by medium (4.61) and small farmers (5.36), respectively. Again, it was observed that specific energy was highest for small farmers followed by medium and large farmers, but energy productivity was lowest in case of large farmers followed by medium and small farmers.

Energy Use and Yield of Paddy Crop

Fig. 1 shows the effect of energy consumption (MJ/ha) on productivity of the paddy crop (kg/ha). A spectrum of energy use by different category farmers in the cultivation of paddy crop is presented in preceding sections. For this purpose, energy use and productivity of total biomass of paddy crop was studied. From **Fig. 1** almost the same level of energy consumption was observed

Fig. 1 Relationship between energy consumption and productivity



for the individual farmers. Due to this trend, it was not possible to study the variation of input energy on the output; i.e. total biomass energy. Although a zigzag variation in output energy was observed probably it was due to other local and individual reasons. There was no close relationship found in energy consumption and productivity for paddy. Extension of knowledge and technology for scientific based crop production has been a limitation in most of the areas of the state but it had a direct impact on production and productivity.

Conclusions

1. A total 76 % of operational energy was consumed for irrigation in paddy crop. This created extreme imbalance in energy consumption pattern and indicated the kind of energy waste practiced by the farmers.
2. The direct and indirect source of energy consumption was 59.7 and 40.3 %, respectively. Electrical energy was the major source of direct energy consumption
3. The commercial source of energy consumption was to the tune of 92.9 % indicating a need for introduction and enhancement of non-commercial energy.
4. Energy productivity was lowest for large farmers followed by medium and small farmers. The energy consumption and productivity of paddy was linearly related with a high positive correlation.
5. Energy management at the farm level needs serious attention both for efficient and economical use of energy vis-a-vis safe guard of agro-ecosystem. Lack of knowledge of scientific recommendation, improper training to use modern means of energy and machine sources and prevailing myth and mindset are the obstacles in efficient energy utilization and need to be addressed through
6. More comprehensive data obtained from different states with appreciable variation in energy input application would be required for such a study.

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Compatibility of Jatropha Oil Bio-Diesel and Petro Diesel as an Engine Fuel Based on their Characteristic Fuel Properties

by

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Abstract

Biodiesel is an environment friendly renewable alternative fuel for diesel engine. Jatropha seeds can be a feedstock to produce a valuable amount of oil to be converted to biodiesel using transesterification reaction. The methyl ester and ethyl ester of jatropha oil was prepared and characterized by various methods to evaluate ash content, kinematic viscosities, relative densities, flash points, fire points, cloud points, pour points, conradson carbon residues, gross heat of combustion and free fatty acid. Most of the fuel characteristics of the biodiesel were quite close to those of petro diesel. However, the conradson carbon residues of jatropha oil and their esters were higher than that of petro diesel.

Introduction

The increasing demand for petroleum based fuels, global warming and environmental pollution has driven the world to search for newer, cleaner and safer sources of fuel. At present, nearly 90 % of the world's energy demand is met by the combustion of non-renewable fossil fuels. As the fossil fuels are limited and it takes millions of years for their formation, their availability may be prolonged by decreasing overall consumption. Various renewable sources of energy have successfully been tried and used by different nations to limit the use of fossil fuels. This renewable source of energy includes solar energy, wind energy, geothermal energy, tidal energy, ocean thermal energy,

Table 1 Potential and production of renewable energy for various sources in India

Source/ Systems	Estimated potential (MW)	Cumulative installed capacity (as on 31 March 2005) (MW)
Solar photovoltaic	20 MW/km^2	2.8
Wind power	45,000	3,595.00
Biomass power	16,000	302.53
Bagasse Co-generation	3,500	447.00
Waste to energy		
Municipal solid waste	1,700	17.00
Industrial waste	1,000	29.50
Small hydropower (up to 25 MW)	15,000	1,705.63
Total		6,099.46

hydropower and others. **Table 1** depicts the renewable energy potential of India and the resources trapped till 2005 (Sharma and Singh, 2009).

Use of the renewable energy has made the nation self-dependent to some extent but still it is far behind in making a significant difference in import of crude oil, which is the need of the present day. In India, the domestic production of crude oil in the year 2008-09 was 33.51 million tonnes, whereas, 128.16 million tonnes of oil (which amount to 79 % of total oil consumed) were imported (http://petroleum.nic.in/petstat.pdf). A new technology, i.e. transesterification reaction of vegetable oil and animal fats, has been applied to produce a renewable fuel: "biodiesel". Biodiesel, an alternative diesel fuel, is made from renewable biological and renewable energy sources, such as vegetable oils and animal fats. It is biodegradable, non-toxic and possesses low emission profiles. It has similar physical and chemical properties with petro-diesel fuel. However, biodiesel properties can sometimes be superior to that of petro-diesel fuel because the former has a higher flash point, ultra-low sulphur concentration, better lubricating efficiency and better cetane number. Biodiesel is an ester based oxygenated fuel from renewable biological sources. The use of edible oils for biodiesel production could be detrimental to food availability. A recent study on the evaluation of 75 non-edible oils as a source of biodiesel identified Jatropha curcas as one of the most promising plants (Azam *et al*., 2005).

Jatropha curcas belongs to the Euphorbiaceae family. It is considered to be native to Central and South America and is widely present throughout Central America, Africa and Asia. Jatropha is a vigorous, drought- and pest-resistant plant, and can grow under a wide range of rainfall regimes ranging from 200 mm to over 1,500 mm per annum. It survives also on barren, eroded lands, and under harsh climatic conditions (Becker and Makkar, 2008). Its seeds contain 30-35 % oil and the plant has a productive life of 40-50 years. The oil content of jatropha varies depending on the types of species and climatic conditions, but mainly on the altitude where it is grown. The study showed that the average oil contents in jatropha curcas L. at the elevation ranges of 400-600 m, 600-800 m and 800-1,000 m were 43.19 %, 42.12 % and 30.66 % of their seed weight, respectively (Pant *et al*., 2006). Traditionally, Jatropha has been used for its oil and other plant parts and derivatives for medicinal purposes and for soap production. This paper deals with the study of jatropha fruits, seeds and fuel characteristics of jatropha oil and their esters.

Materials and Methods

The jatropha oil used in this experiment was procured from market. The characteristics of raw oil as well as its ethyl and methyl esters were determined by using the following methods.

Relative Density

The relative density of the fuels at 15 ºC was determined as per **IS:1448 [P: 32] (1992)**. Empty 50 ml pyknometers were weighed. The pyknometers were then filled with fuel samples and weighed. The samples were maintained at 15 ºC by keeping them in a Saveer Biotech walk-in temperature control chamber. The weights of the empty pyknometers were subtracted from the weights of the filled ones to get the weight of the fuel samples. This value, when divided by the volume of the fuel sample, gave the density (ρ_F) of the fuel sample at 15 ºC. The density of distilled water (ρ_w) at 15 ºC was also determined.

Relative density = Density of the fuel at 15 ºC / Density of the water at 15 ºC

Kinematic Viscosity

Kinematic viscosity of the samples was measured by using a Redwood Viscometer (WISWO make). Time of gravity flow in seconds of a fixed volume of the fluid (50 ml) was measured as per **IS:1448 [P:25] (1976)**. The experiment was performed at 38 ºC. Kinematic viscosity was calculated using the relationships given by **Guthrie (1960)**.

$$\nu_k = 0.26\,t - (179 / t)$$

When $34 < t < 100$ and

$$\nu_k = 0.24\,t - (50 / t)$$

When $t > 100$

where

ν_k = Kinematic viscosity in centistokes

t = Time for flow of 50 ml sample in second

Cloud and Pour Points

The Cloud and Pour point of fuel samples were determined as per **IS:1448 [P:10] (1970)** using the Cloud and Pour point apparatus. The apparatus mainly consisted of 12 cm high glass tubes of 3 cm diameter. These tubes were enclosed in an air jacket, which was filled with a freezing mixture of crushed ice and sodium chloride crystals. The glass tube containing the fuel sample was taken out from the jacket at 1 ºC interval as the temperature fell, and was inspected for cloud/pour point. The point at which a haze was first seen at the bottom of the sample was taken as the cloud point. The pour point was taken to be the temperature 1 ºC above the temperature at which no motion of fuel was observed for five seconds on tilting the tube to a horizontal position.

Flash and Fire Point

The flash and fire point of the fuel samples was determined as per **IS:1448 [P:32] (1992)**. A Pensky Martin Flash Point (closed) apparatus was used to measure the flash and fire points of the fuel samples. The sample was filled in the test cup up to the specified level and was heated and stirred at a slow and constant rate. The temperature was measured by a thermometer. At every 1 ºC temperature rise, a flame was introduced for a moment with the help of a shutter. The temperature at which a flash appeared in the form of sound and light was recorded as flash point. The fire point was recorded as the temperature at which fuel vapour caught fire and stayed for a minimum of five seconds.

Ash Content

The ash content of diesel and jatropha oil was measured as per the standard **ASTM D482-IP 4** of the Institute of Petroleum, London. An electric muffle furnace of Sonar make was used in the experiment. In order to measure the ash content, a sample was taken in a silica dish. The dish was first weighed empty and then with the fuel sample. The sample weight was obtained from the difference between the initial and final weight of the dish. The sample was then placed in the muffle furnace and heated at 775 ± 25 ºC for two hours. The dish was then cooled to room temperature in a desiccator. Thereafter, the dish was weighed to the nearest 0.01 mg using an electronic balance. The ash content was obtained using the equation given below.

$$A_s = (W_a / W_s) \times 100$$

where,

A_s = Ash content, percent

W_a = Weight of ash, g

W_s = Weight of sample, g

Conradson Carbon Residue

Carbon residue was determined for different fuels by using a carbon residue apparatus. The measurement was made in accordance with the **ASTM D189-IP 13** of the Institute of Petroleum, London. This procedure determined the amount of carbon residue left after evaporation and pyrolysis of an oil. It was intended to provide some indication of relative coke forming properties. In this method, 10 g weight to the nearest 5 mg of each fuel sample was weighed free of moisture and other suspended matter into an iron crucible of the apparatus. The crucible was then placed in the centre of a skidmore crucible of the apparatus and the sand was leveled in the large sheet iron crucible and then the skidmore crucible was set on it in the exact centre of the iron crucible. Thereafter, the covers were applied to both the skidmore and iron crucibles loosening the latter fitting to allow free exit to the vapours as they formed. The fuel sample was then heated with a high strong flame from a gas burner for 20 min. When the smoke appeared on the chimney, immediately the burner was moved or tilted so that the gas flame played on the sides of the crucible for the purpose of igniting the vapours. After that the ignited vapour was burnt uniformly with the flame above the chimney for another period of time. When the vapour ceased to burn and no further smoke was observed, the burner was adjusted and the heat was held as at the beginning to make the bottom and the lower part of the sheet iron crucible, a cherry red for about 15 min. Thereafter, the burner was removed and allowed to cool until no smoke appeared. The cover of the skidmore was then removed with a tong and it was cooled and weighed. The percentage of carbon residue on the original sample was then calculated using the equation as given below:

$$C_r = (W_c / W_s) \times 100$$

where

C_r = Carbon residue, %

W_c = Weigh of carbon residue, g

W_s = Weight of the sample, g

Acid Value

Free fatty acids present in a vegetable oil may be corrosive to some engine parts. At elevated temperatures, free fatty acids may react with many metals producing fatty acid metal salts thus increasing wear. Acid value is, therefore, an important characteristic to be measured. The acid value or number defined as the mg KOH required to neutralize the free fatty acid present in one gram of sample. The total acid value of different fuel samples was measured as per method describe by Cox and Pearson, 1962. A known amount of sample was dissolve in 50 ml of the neutral solvent (neutral solvent is the mixture of 25 ml ether, 25 ml alcohol and 1 ml of 1% phenolphthalein solution and titrated with aqueous solution of KOH of 0.1 N).

The total acidity was calculated using following equation:

$$A_v = (56.1\ N \times T_v) / W_s$$

where

A_v = Acid value, mg of KOH/g

T_v = Titrate value, ml

N = Normality of the potassium hydroxide solution

W_s = Weight of sample, g

The oil contained large amounts of free fatty acids (FFA) that appeared as brown grease (FFA > 15 %). High FFA content (> 1 % w/w) will cause soap formation which gives rise to the formation of gels making the separation of products exceedingly difficult. As a result it had low yield of biodiesel (ester) using alkaline catalyst. Freedman and Pryde (1982), Liu (1994), and Mittelbach *et al.* (1992) have mentioned that the oil should not contain more than 1 % FFA for alkaline catalyzed transesterification reactions. As FFA levels increased this became undesirable because of the loss of feedstock as well as the deleterious effect of soap on glycerin separation (Canakci and Gerpen, 2001). The soap promoted the formation of stable emulsions that prevent separation of the biodiesel from the glycerin during processing. Therefore, it was necessary to reduced FFA to an optimum level for further processes.

Results and Discussion

Fuel Characteristics of jatropha oil, diesel and their methyl and ethyl

Table 2 Fuel characteristics of jatropha oil, diesel and their biodiesels

Properties	Jatropha oil	Diesel	Methyl ester	Ethyl ester
Ash content, %	0.0999	0.008	0.0088	0.0098
Kinematics Viscosity at 38 ºC, cS	32.665	3.078	4.912	5.284
Relative density at 15 ºC	0.882	0.839	0.873	0.879
Flash point, ºC	229	63	198	195
Fire point, ºC	235	70	206	201
Cloud point, ºC	9	−3	4	2
Pour point, ºC	3	−9	1	−1
Carbon residue, %	6.35	0.14	0.68	0.57
Gross Heat of combustion, MJ/kg	40.80	45.58	39.88	41.50
Free fatty acid (FFA), %	16.4	0.19	0.23	0.27

esters were determined and are presented in the **Table 2** and in the **Figs. 1** to **8**.

The **Fig. 1** revealed that the ash content in jatropha oil was very high; about 1148.75% higher as compared to diesel, where as the ash content of methy ester and ethyl ester was 0.0088 and 0.0098%, respectively. This was within the range of recommended maximum ash content levevl of 0.01 percent in diesel fuel IS:1460 (1974).

Kinematic viscosity of diesel, jatropha oil and its methyl ester and ethyl ester at 38 ºC are given in **Fig. 2**. It is clear from the Figure that kinematic viscosity of jatropha oil was very high (32.67 cS) as compare to diesel (3.08 cS) while that of methy ester and ethyl ester was 4.912 and 5.284 cS, respectively, at 38 ºC. The decrease in kinematic viscosity was the important fuel property of the transesterified jatropha oil. This indicated that the flow capability of raw jatropha oil had been increased to a significant extent by transesterification. This increase in the ability to flow would induce complete burning of the fuel without any ignition delay. The kinematic viscosity of methyl and ethyl ester was 1.6-1.7 times than that of the diesel (3.078 cS). The kinematic viscosity of jatropha ester was in the range of diesel fuel at 38 ºC (2.0 to 7.5 cS) according to IS:1460 (1974). Foidl *et al.* (1996) reported the kinematic viscosity of jatropha oil and its methyl and ethyl ester as 52.0, 4.84 and 5.54 cS, respectively, at 30 ºC.

Fig. 1 Ash content of diesel, Jatropha oil

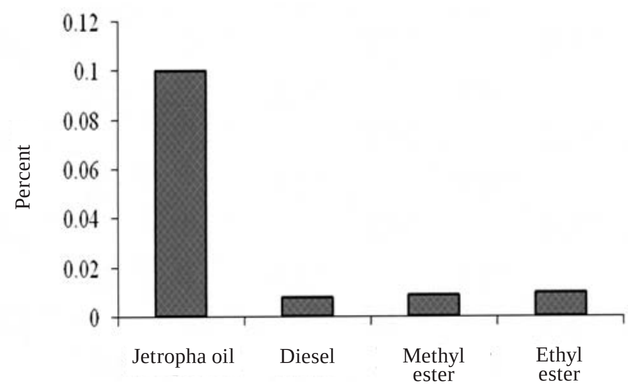


Fig. 2 Kinematic viscosity of jatropha oil, diesel and their biodiesels methyl ester and ethyl ester at 38 ºC

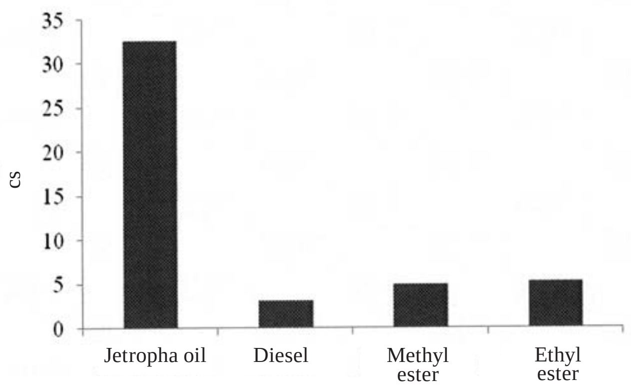


Fig. 3 Relative density of diesel, jatropha oil

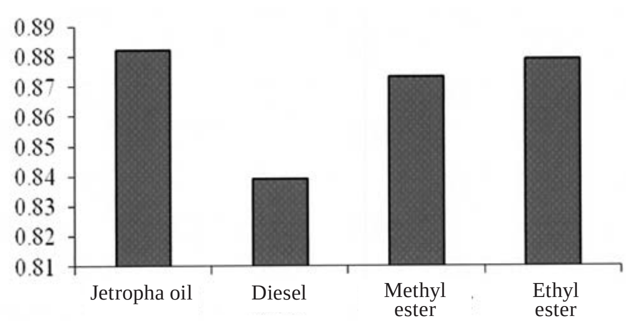
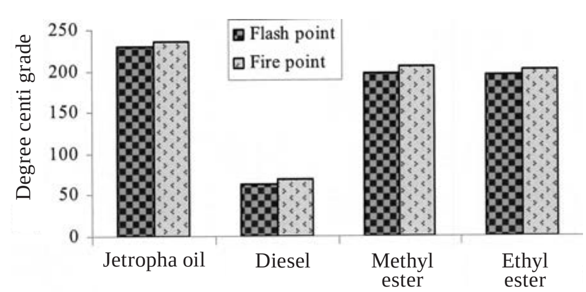


Fig. 4 Flash point and fire point of diesel, and their methyl, ethyl esters at 15 ºC jatropha oil and their esters



This clearly showed that most of the problems faced with vegetables oils as fuel for diesel engines will be taken care of by the transesterification of vegetable oils.

Relative density of diesel, jatropha oil and its methyl and ethyl esters are presented in **Fig. 3** and shows that the relative density of jatropha oil was 0.882, which is 5.1 percent higher than that of diesel (0.839) at 15 ºC. The relative density of methyl ester and ethyl ester was 0.873 and 0.879, respectively, at 15 ºC, which was 4.0 to 4.8 percent higher than that of diesel. Thus, biodiesels will have higher mass flow rate due to their high relative density. Lower relative densities of bio-diesel compared to raw oils have also been reported by Foidl *et al.* (1996).

It is clear from **Fig. 4** that the flash point of jatropha oil and its methyl and ethyl esters was much higher (195-229 ºC) than that of diesel (63 ºC), thus, ensuring more safety during transportation, storage and handling. The fire point of jatropha oil and its methyl and ethyl esters was also much higher (201-235 ºC) than that of diesel (70 ºC). It is also obvious from **Fig. 4** that the flash point and fire point of biodiesel/esters were lower than that of raw jatropha oil. The observed result of high flash point and fire points of biodiesel were in accordance with the findings of Foidl *et al.* (1996) who reported the flash point of jatropha oil as 240 ºC.

Cloud point and pour point of diesel fuel, jatropha oil and its methyl and ethyl esters are given in **Fig. 5**. It is clear from the Figure that the cloud point and pour point of jatropha oil was high 9 ºC and 3 ºC, respectively, while the cloud point and pour point of diesel fuel was −3 ºC and −9 ºC, respectively. The Fig. also shows that the cloud point and fire point of biodiesel was lower than that of raw jatropha oil. The cloud point indicated the start of clogging in fuel lines and filters because of the presence of saturated fatty acids. The cloud point of methyl and ethyl ester was 4 ºC and 2 ºC, respectively. The pour point of of methyl and ethyl ester was 1 ºC and −1 ºC, respectively. These values of biodiesel differed little from that of diesel (−3 ºC and −9 ºC). Therefore, like diesel, jatropha biodiesel will also be suitable, not only for the tropical region, but also for moderate temperature region in engine operation.

Fig. 6 shows the percent weight of conradson carbon residue of diesel, jatropha oil and its methyl and ethyl esters. Raw jatropha oil had a very high carbon residue content of

Fig. 5 Cloud point and pour point of diesel

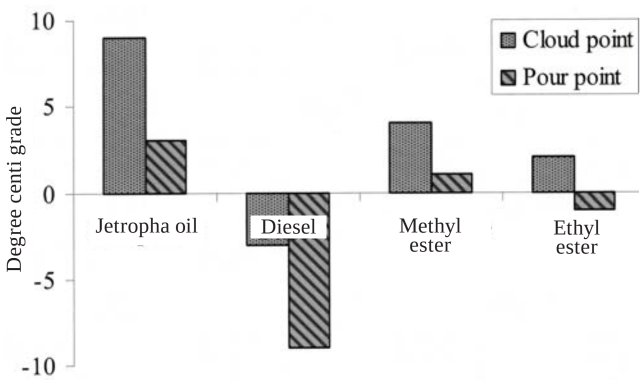


Fig. 6 Conradson carbon residue of jatropha jatropha oil and their biodiesel oil their biodiesel and diesel

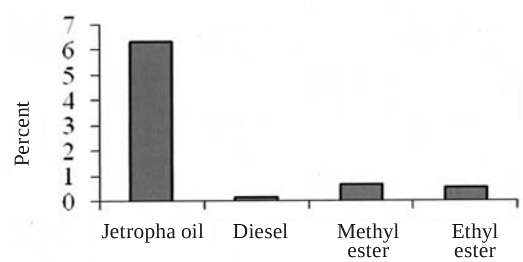


Fig. 7 Heat value of jatropha oil, their

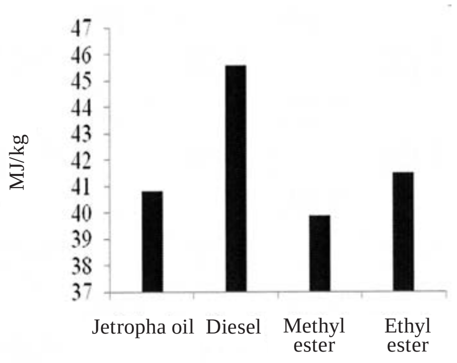
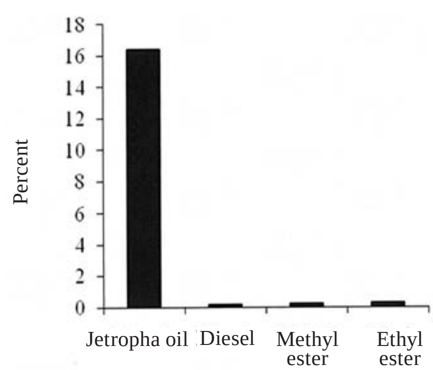


Fig. 8 Free fatty acid of jatropha oil, biodiesels and diesel their biodiesels and diesel



6.35 %, while that of diesel had 0.14 %. The maximum recommended carbon residue level in diesel fuel, as per IS:1460-1974, is 0.2 percent. It is also clear from the **Fig. 6** that esterification of raw jatropha oil reduced the carbon residue content to a great extent. The carbon residue of methyl ester and ethyl ester was 0.68 and 0.57%, respectively, which was 307-386% higher than that of diesel. Ouedraogo *et al.* (1991) also reported the carbon residue content of jatropha oil to be much higher than that of diesel fuel.

Fig. 7 revealed that the gross heat value of raw jatropha oil was 40.8 MJ/kg and was about 10.5 % less than that of diesel (45.58 MJ/kg). This was because of the presence of oxygen (10-11 %) in the jatropha oil. The gross heat of combustion of jatropha methyl ester and ethyl ester was 39.88 MJ/kg and 41.5 MJ/kg, respectively, which was 12.5 and 8.95 % less than that of diesel.

At elevated temperatures, fatty acids react with metal parts and fatty acid metal can be introduced into the engine cylinder and can increase wear. It is evident from the **Fig. 8** that the free fatty acid (FFA) of raw jatropha oil was very high (about 16.4 %) where as diesel had 0.19 %. The free fatty acid and acid value of jatropha oil was reduced from 16.4 % to 0.23 % for methyl ester and 0.27 % for ethyl ester by the pretreatment of high free fatty acid oil followed by transesterification. On duel step process, the value of FFA reduced drastically. The maximum recommended level of total acidity of diesel was 0.50 mg of KOH/g (IS:1460-1974). Therefore, the free fatty acid of biodiesel was quite close to that of the diesel fuel and within the recommended level of BIS.

Conclusion

The use of jatropha oil as diesel fuel depended on its characteristic fuel properties. The fuel properties, such as, viscosity, ash content, carbon residue, flash point and acid value of jatropha oil was far greater than that of petro diesel and therefore, made it unsuitable for use as fuel in diesel engines.

Esterification of jatropha oil to methyl and ethyl ester brought the fuel properties closer to that of petro diesel. The viscosity of methyl and ethyl ester was within the recommended limit. It could also be concluded from the study that the physical and chemical properties of jatropha biodiesel were in agreement with those of petro diesel and meet the existing standards for vegetable oil derived fuel. Therefore, it could be used as an alternate fuel in compression ignition engines.

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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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Occupational Health Hazards of Farm Women in Harvesting Clusterbean (Guar) and Preventive Measures: **Sudesh Gandhi**, Deptt. of Family Resource Management, College of Home Science, CCS Haryana Agricultural University, Hisar, 125004 INDIA sggandhi3@gmail.com; **M. Dilbaghi**, same; **Manju Mehta**, same.

Guar harvesting, besides being a tiring task, involves a number of health hazards. Pods of the guar plant become very hard after drying and prick into hands of the worker while cutting. The field experiment was conducted on 10 women respondents in CCSHAU farms harvesting guar in the forenoon for one hour with existing and improved method. In existing method, main problems faced while harvesting of guar were irritation (ms = 4.0), hands smeared with dust (ms = 4.0) and injury in hands (ms = 3.5). To overcome the problem, improved method was used for guar harvesting that consisted of use of safety hand gloves and improved serrated sickle. Three types of safety gloves were tested and best gloves were further selected for ergonomic evaluation. Effect of gloves in relieving them from hazards revealed that some of the health hazards were completely removed viz cuts in hands, hands smeared with dust and swelling in hands (100 %). There was 28.8 percent reduction in RPE while cutting guar using improved sickle with gloves. Improved methods resulted decrease in musculo-skeletal problems. Maximum reduction in pain was observed in palm with combination of improved sickle with gloves (40.5) followed by in fingers (35.9 %). Overall discomfort score was 9.2 which reduced to 6.7 with safety gloves. And, it also increased the area covered (3.0 %). Therefore, propagation of appropriate technology is need of the hour as preventive measures which would be helpful in reducing the drudgery and increasing the efficiency.

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Effects of three types of chemical fertilizers on the soil penetration resistance: **Jafar Massah**, Assist. Prof., Department of Agrotechnology, College of Abouraihan, University of Tehran, Tehran, IRAN, jmassah@ut.ac.ir

Fertilizing is component of a maintenance program for trees and agricultural crops. Fertilizers have typically been used to provide certain essential elements to enhance the growth and health of the agricultural crops and trees. In this research effect of additions of three types of commonly used chemical fertilize (urea, diammonium phosphate and potassium chloride) on the soil penetration resistance were studied. Cone index was measured with a cone penetrometer which was mounted on a digital cone penetrometer. Tests were carried out in twenty one plastic containers which filled of the loam soil. The treatments included no fertilizing (NF), urea fertilization (UF), diammonium phosphate fertilization (DF), potassium chloride fertilization (PF), double the UF (2UF), DF (2DF) and PF (2PF). Tests were replicated three times for each of the treatments with three measurements of penetration resistance per each container. Results of experiments showed consumption of fertilizers increase soil penetration resistance. Among the treatments, the 2UF had the highest value of soil resistance in a certain depth.

■■

Development and Evaluation of Mechanical Picking Heads for Citrus Fruits Harvesting

by
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Abstract

Two prototypes of harvesting tools for rotary picking heads and electrical scissors harvesting head were designed, fabricated and evaluated to reduce the number of manual pickers needed and maximize productivity and reduce harvesting costs. The rotary picking head was used for harvesting of Washingtonia and Valencia oranges with four types of rotary cones with rotational speeds of 300, 450, 600, and 750 rpm. The electrical scissors harvesting head was used for harvesting of Washingtonia and Valencia oranges, Mandarin and Lemon citrus fruits using five different labors. The important results were:

- The picker productivity was increased from 0.890 and 0.67 ton/day using traditional methods to 1.663 and 1.236 tons/day for picking Washingtonia and Valencia oranges, respectively, using the rotary picking cone. Picker productivity was increased from 0.890, 0.671, 0.423 and 0.102 ton/day using traditional methods to 1.029 and 1.224, 0.647 and 0.126 tons/day for picking Washingtonia and Valencia oranges, Mandarin and Lemon fruits, respectively, using mechanical methods of electrical scissors.
- Using mechanical methods maximized the picked fruit quality (more than 85 % for Grade I- Extra fancy) and minimized the mechanical fruit damage (less than 1 %) compared with traditional picking.
- The authors recommended the use the rotary picking head and electrical scissors harvesting head as a simple picking head design that used local material for fabricating and was easy to use for picking citrus fruit by farm labors to decrease the hazards of platforms and lifting methods used with traditional methods. In addition to increasing the rate of fresh market exporting, the picking cost was reduced, the farmer would benefit and national income would be increased.

Introduction

Egypt stands among the largest citrus producing countries in the world and occupies the fourth rank in production amongst the Mediterranean basin countries. Egyptian citrus has advantages in terms of yield and fruit quality, early ripening, relatively low labor cost and is close to international importing markets. Consequently, this creates a unique situation for Egyptian and exported quantities have been generally increasing. Citrus is considered the most important fruit crop being cultivated in Egypt. It represents about 31.6 % of the total cultivated fruit area (359,703 fed). However, the total citrus production in Egypt is about 40.1 % of the total fruit production (7,192.715 million tons). The volume of fresh citrus fruit exports is about 21.8 % of the total citrus fruit production (630.000 tons). Oranges represents 62 % of the citrus fruit followed by mandarin with 27.5 % and limes with 10.9 % of the total citrus area in Egypt (Anonymous, 2003).

Seamount and Opitz (1973) examined the overall efficiency and the various picking activities involved in the use of an ‘auto picker’ compared to the use of ‘ladder and bag’ picking. The results showed that the time required to pick a box of fruit using a ladder was 8.07 min/box and with the 'auto picker' was 6.46 min/box. Hence, the two-man positioning machine increased the productivity and picking efficiency of each picker. However, there was no such increase in productivity with the use of picking platforms. Sumner (1978) classified fruit harvesting machines as a contact machine and mast removal machines according to their method of fruit removal. Contact machines employed either a spindle or a comb-like mechanism to detach the fruit. The thick foliage and limb interference of the tree canopy limited the fruit removal with these machines to about 70 %. The positioning mechanism, common to all harvesters of this type, was the principal factor affecting initial cost and harvest rate. The combination of high cost, low fruit removal efficiency and a harvest rate of only 5 to 10 m high trees per hour discouraged the development. Mass removal machines employed some type of external shaking force, which was transmitted to the fruit through the limbs or foliage. This force was generated by a mechanical vibration source that attached to the trunk, limb or foliage of the tree, or by oscillating air or water pulses which shake the foliage.

Ben-Tal (1983) stated that harvesting equipment can operated at maximum productivity when the workspace was organized to minimize inefficient obstacles, standardize fruit presentation, provide sufficient alleyways, and maximize fruit density on uniform growth planes. Large equipment systems required wide row spacing while smaller systems can work in a more confined grove configuration. Optimally, the fruit should be grown in a hedge row configuration where the plants produce a maximum number of fruits over the surface area.

O'brien *et al.* (1986) categorized the elements of harvest operation into the following processes: detecting the fruit, selecting those to be harvested, detaching the selected fruits, collecting or gathering detached fruits, and finally containerizing them. The possibility of integrating two or more of these processes was also indicated. As a matter of fact, detaching is considered the essential process that needs to have a more efficient tool or mechanical aid since detecting and selecting the fruits to be harvested could be integrated into a single action and done either by the human worker before detaching in the simple systems or by machine vision technique in the more complicated mechanization system process. Also, they added that fruit detachment may be done by employing direct contact methods such as cutting, pulling, snapping, twisting, stripping and impacting. Indirect methods, such as using inertial force, that respond to the attachment as a result of a difference in relative acceleration could also be used.

Grand d'Esnon *et al.* (1987) developed a rotating cup picking mechanism on the end of a robotic device for apple harvesting. Suction was applied to the apple fruit in the picking mechanism. Their results indicated that 75 % of the picked fruits retained their stems. Herrell *et al.* (1990) designed and constructed a robotic citrus picker and used a rotating lip design for the developed detaching device. They also used a kind of a machine vision arrangement for detecting and selecting the fruits to be harvested. During the last few years, some research work has been conducted in Egypt to improve simple and small fruit harvesting devices with low cost to suit the small holdings. Abo EI-Kheir (1993) designed and developed a small hand-held harvester machine arm to be used in harvesting lime fruit. An arc shape cutting blade was used to control catching and cutting the fruit peduncle. Evaluation of the harvester performance indicated that, the percentage of picked fruits to the total number of fruits ranged from 90 % to 100 %, but the effect of utilizing this arm on the worker, productivity was not mentioned.

Whitney *et al.* (1996) analyzed harvesting data collected during the 1993?1994 season for four pairs of pickers in orange trees with fruit yields from 30 to 76 t/ ha, fruit weight from 160 to 235 g and tree heights from 3.7 to 5.5 m. Each picker used a conventional ladder and bag. The average harvesting rate per picker was ranged from 241 to 376 kg/h and harvesting increased by 40.8 kg/h for an approximate increase of either 20 t/ha in yield or 50 g in fruit weight, or a 2 m decrease in tree height.

Abou Elmagd *et al.* (2002) designed, fabricated and tested an orange detacher prototype in picking Washingtonia oranges. Their results indicated that the minimum fruit detachment time was obtained at a friction coefficient of about 0.81 for Washingtonia variety. The cone rotating speed of 680 rpm gave the best results for the shortest remaining twig height of 0.88 mm and optimum cone angle of 52º. The developed picking method was superior when compared to the manual traditional picking method since it accomplished about (87.9 %) of fruits grade (I), low percentages of fruit, with twig (9 %), and fruits without calyx (3 %). Brown (2002) concluded that Florida-harvested 95 % of its 245.000 ha of oranges for processing into juice. Until recently, all fruit was hand harvested. With the supply of workers decreasing and harvest cost increasing, harvest cost must be reduced about 50 % to effectively compete in free-trade markets. A harvesting program funded in 1994 by Florida citrus growers to develop improved methods for harvesting has now produced at least 8 different harvesting systems. These can be economically used in various production areas by the juice industry. Cost savings of 10 to 75 % are possible in the future, depending on the type of grove and the appropriate harvesting system. Futch *et al.* (2004) reported that during the last 40 years, significant efforts have been devoted to improve productivity and mechanize the harvesting of the Florida citrus crop. Initial work focused on ways to improve the hand harvesting operation by providing harvesting aids to improve worker productivity. Through these studies, it was determined that the hand harvesters spent at least 25 percent of their time in activities that were not directly related to fruit removal from the tree.

Sanders (2005) concluded that mechanical harvesting provides a significantly higher harvesting rate over manual picking. The maximum picking rate of manual pickers is 0.5 t/h; whereas the picking rate of trunk shaking harvesters is 10 t/h and of canopy shakers is 25 t/h. Hence, a mechanical harvester can replace 20-50 manual pickers. Manual harvesting offers the benefits of maximum fruit selection and maximum product quality; but has the disadvantages of uncertain labor availability and a relatively low picking rate. Also, he added that the harvesting of citrus fruit represents 35-45 % of total production cost. Hence, an improvement in the efficiency of this one operation has a significant effect upon enterprise viability and profitability. The traditional manual harvesting method is very labor intensive, and thus expensive. Mechanical harvesting methods have been widely researched and significantly improved. Burks *et al.* (2005) identified that automated solutions for fresh market fruit and vegetable harvesting have been studied by numerous researchers around the world during the past several decades. However, very few developments have been adopted and put into practice. The reasons for this lack of success are due to technical, economic, horticultural, and producer acceptance issues. Viable solutions will require engineers and horticultural scientists who understand crop-specific biological systems and production practices, as well as the machinery, robotic, and control issues associated with the automated production systems.

Problem Statement

The basic problems of fruit harvesting are because it is a labor intensive operation. Citrus is one of the major tree crops which are still being harvested by hand grasp. Citrus production, especially orange and mandarin, are basically oriented towards the fresh market, which requires harvesting fruits without mechanical damage and assuring that fruits are harvested with its calyx for good storage and long shelf life suitable for exporting. In Egypt, during the last two decades a consistent labor supply for hand harvesting has been more difficult to obtain even as yields of the citrus crop have been steadily increasing. These concerns led to the development of a citrus mechanical harvester. Therefore, the main goal of this study is to design, fabricate and evaluate simple fruit harvesting tools to remove or aid in the removal of citrus fruit, thus, reducing the number of hand harvesters needed and maximizing manual picker productivity that will reduce harvesting costs.

Fig. 1 The main components of rotary cone picking head

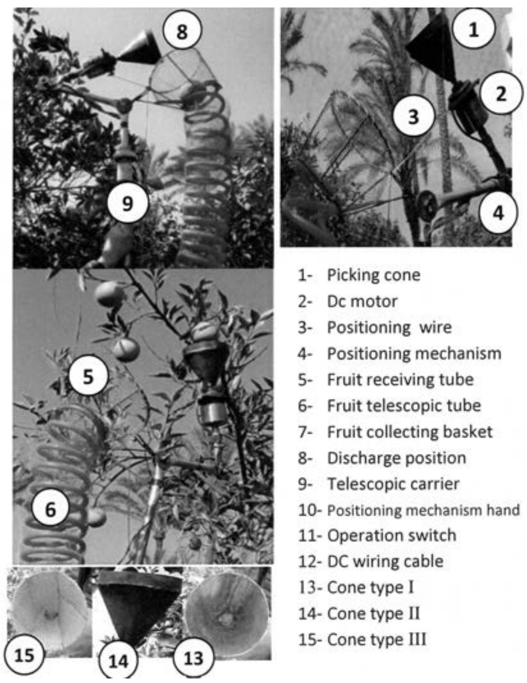
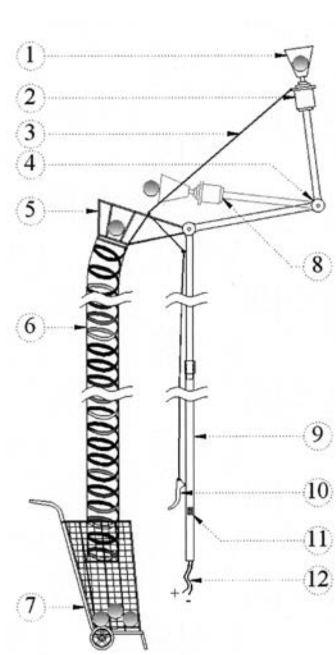


Fig. 2 Schematic diagram of rotary cone picking head



Material and Methods

Materials

In this study, two designed prototypes of harvesting tools, namely rotary picking head and electrical scissors harvesting head, were evaluated under field harvesting conditions. The construction and the main components of both types of harvesting heads could be explained as follows:

Rotary Picking Head:

The designed rotary picking head illustrated in **Figs. 1** and **2** consisted mainly of:

1- Detaching mechanism: it is a metal cone 11 cm high and 11 cm diameter with a cone angle of 36º (El Khawaga, 1999). The fruit picking method by rotary picking head depended on the action of torsional shear to the supporting twig of the fruit through a small bottom (calyx), which resulted in a separation process while rotating the fruit inside the rotary cone. Four types of detachment mechanisms (rotary cone) was designed and tested as the follows.

Type I: Metal cone without upper edge.

Type II: Metal cone equipped with upper edge (1.5 cm high with the same upper cone diameter).

Type III: Metal cone without upper edge and covered with a rubber layer on the inner cone surface.

Type IV: Metal cone with upper edge and covered with rubber layer on the inner cone surface.

2- Housing of the detachment mechanism that included a telescopic carrier (2-5 m), electric DC motor, battery (12 V-70 Ah) and operation switches/wiring cables. In this housing the detachment unit was fixed on the shaft of electrical motor as a power source for rotary picking head, while the electrical motor was fixed at the upper end of the telescopic carrier.

3- Positioning mechanism that was used to insert the picking head between the tree branches and select the desired mature fruits to be harvested then dropped it in the fruit receiving tube.

4- Fruit receiving and collecting mechanism: consisted of: a) Fruit receiving telescopic tube fixed on the housing mechanism to receive the detached fruit and transport to the collecting basket. b) Fruit collecting basket attached at the lower end of the receiving tube to collect the citrus fruits detached from tree. This basket was equipped with two wheels to make it easy during moving between trees in the field and. also easy to empty.

Electrical Scissors Harvesting Head:

The construction of the electrical scissors harvesting head is shown in **Figs. 3** and **4** and included the following components:

1- Cutting mechanism that consisted of:

a) Cutters (scissors) with one fixed and other movable

b) Electric DC motor and battery (12 V, 70 Ah) as the power source for the reciprocating speed of the scissors.

c) Cam, for converting the rotational speed to reciprocating speed for the mobile scissor to cut the fruit twig.

d) Wiring cable and operation switch for connecting the battery with the electrical motor and switching on/off.

e) Fixing base for the electrical motor with the cam and scissors.

2- Positioning and housing mechanism

This consisted of a telescopic carrier, which can be changed its height according the fruit height on the tree (3-5 m) for adjusting cutting angle of selected fruits to be harvested and carrying out the cutting mechanism at the upper end.

1- Cutting mechanism

2- Positioning mechanism

3- Fruit receiving mechanism

3- Fruit receiving and collecting mechanism consisted of:

a) Fruit receiving screw tube fixed in a suitable position on the housing mechanism to receive the detached fruit transport to the collection basket.

b) Fruit collection basket that attached at the lower end of the telescopic receiving tube to collect a mass of detached fruits. This basket was equipped with two wheels for easy movement during between trees and for emptying.

Performance Test and Evaluation

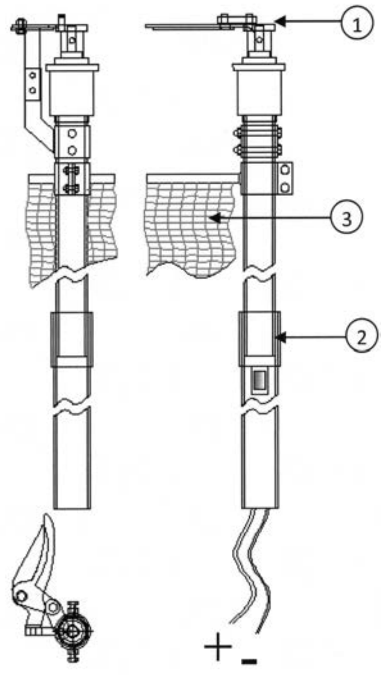
Performance Test of Rotary Cone Picking Head:

The prototype of the rotary cone picking head was evaluated and tested for harvesting Washingtonia and Valencia orange fruit varieties (Citrus aurantium) using four types of rotary cone picking heads under four different rotational speeds (300, 450, 600 and 750 rpm; and 1.73, 2.54, 3.45 and 4.31 m/s, respec-

Fig. 3 The main components of electrical scissors head

1-Cutting mechanism
2-Positioning mechanism
3-Fruit receiving mechanism

Fig. 4 Schematic diagram of electrical scissors harvesting head



tively).

Performance Test of the Electrical Scissors Harvesting Head:

The prototype of the electrical scissors harvesting head (**Fig. 3**) was evaluated and tested during harvesting of Washingtonia and Valencia oranges, Mandarin (citrus nobilis —King Mandarin), and lemons (citrus aurantifolia —Lemon) using five different labors. The field experiment and test evaluation of the rotary cone picking and electrical scissors harvesting heads were carried out during the harvesting seasons of 2007 and 2008 at the citrus farm attached to the Mansoura University.

Measurements

Citrus Tree Characteristics:

Citrus tree canopy characteristics that effect on the performance of the designed harvesting tools were investigated and measured. They were tree height, mean diameter of tree canopy, height of the first branch, tree spacing, layers of fruit distribution and percentage on the tree canopy.

Citrus Fruit and its Twig Properties:

The important physical and mechanical properties of citrus that affected the performance of the designed harvesting tools were measured, such as fruit mass, major, minor and mean diameters, fruit twig length/diameter and cutting force by the torsional torque action on the fruit twig as described by El Khawaga (1999). The linear dimensions were measured by a digital caliper to an accuracy of 0.01 mm. The fruit mass was measured by electronic digital balance to an accuracy of 0.001 g. Three random samples of fruit (each sample was 20 fruits) were taken from four different citrus varieties for measuring physical and mechanical properties. Twig diameter was measured with a digital caliper directly after the detachment of the fruit.

Total Harvesting Time and Productivity:

The total harvesting time and labor productivity were used to evaluate the performance of the prototypes in comparison with traditional method (hand picking). The total harvesting time was recorded for a full working day to determine the average labor productivity using the different harvesting tools (ton/day). The total harvesting time included selecting, detecting and detaching fruit to be harvested, collecting or gathering detached fruit in the basket and emptying it and the time required for moving harvesting tools between trees inside the field.

Quality of Picked Citrus Fruits:

Five collecting boxes were taken randomly for each harvesting method to estimate the quality of picked orange fruits (Washingtonia and Valencia). The fruit in each box was sorted into four grades: Grade I (extra fancy), with calyx; Grade II, without calyx; Grade III,with twig and Grade IV, damaged (fruit with cracks), according to the practices of the El-Wady Company for Exporting Agricultural Products. The number of citrus fruits for each grade was recorded and the percentage of all grades was then determined. The quality of picked fruits using the electrical scissors head was evaluated by sorting the picked fruits into four grades according to the length of fruit twig (Grade I, included fruits with twigs less than 0.5 cm; Grade II, included fruits with twigs of 0.5-2 cm and Grade III, included fruits with twigs more than 2 cm). However, the Grade IV, included the percentage of damaged fruits (which dropped out of the receiving tube).

Table 1 Physical properties of some citrus fruits and its twig

Measurements		Washingtonia orange	Valencia orange	Mandarin	Lemon
D_1, mm	Min.	57.0	57.0	51.6	32.0
	Max.	80.0	70.0	60.0	40.0
	Av.	**67.0**	**63.3**	**55.1**	**36.3**
	SD	0.56	0.31	0.31	0.28
D_2, mm	Min.	58.0	63.0	38.0	34.0
	Max.	78.0	78.0	47.0	38.0
	Av.	**66.2**	**71.6**	**42.4**	**35.6**
	SD	0.54	0.36	0.25	0.14
Mass, g	Min.	109.0	110.0	80.0	25.0
	Max.	248.0	193.0	105.0	32.0
	Av.	**173.4**	**144.4**	**70.9**	**28.1**
	SD	35.8	21.6	7.09	2.53
Twig diameter, mm	Min.	2.80	2.40	2.10	1.73
	Max.	4.60	3.10	2.91	2.18
	Av.	**3.40**	**2.79**	**2.61**	**1.83**
	SD	0.63	0.24	0.39	0.71
Cutting force of twig, N	Min.	76.52	43.65	48.73	38.15
	Max.	95.16	74.56	69.17	63.79
	Av.	**83.78**	**64.26**	**61.32**	**59.81**
	SD	0.62	1.11	2.17	2.31

Results and Discussions

Citrus Tree Canopy Characteristics

The average value of the tree height for all citrus varieties of Washingtonia and Valencia orange, Mandarin and Lemon fruits were 4.1, 4.6, 4.4 and 4.02 m, respectively. The average value of tree canopy diameter was 5.0 m for all citrus varieties. The first branch on the tree start at height of 0.5-0.6 m from the ground surface with 4-5 main branches for each tree. The average value of citrus tree spacing was 4 × 4 m as shown in **Fig. 5**. The maximum fruit distribution percentages on citrus trees were found on the outer circumference of the citrus canopy. The average value of fruit distribution percentages on different layers of tree height are shown in **Fig. 6**.

Physical Properties of Fruit and its Twig

The minimum, maximum, average values and standard deviation (SD) of physical properties of some citrus fruits varieties (Washingtonia and Valencia orange, Mandarin and Lemon fruits) were measured, analyzed and summarized in **Table 1**. Also, the minimum, maximum and average values of twig diameter and cutting force of fruit twig for citrus fruits under study were included. From this table, it could be concluded that there are differences between the average values of physical properties measurements for all citrus fruits under study. These differences were higher for fruit mass than other measurements.

Performance Evaluation of the Rotary Picking Cone Head

Cone Productivity:

The labor productivity using rotary cone picking head types were evaluated under four different rotational speeds of 300, 450, 600 and 750 rpm for harvesting of Washingtonia and Valencia orange fruits. The results are illustrated in **Fig. 7**.

From **Fig. 7** it may be seen that increasing the cone rotary speed up 600 rpm for picking Washingtonia and Valencia oranges gave a decrease in detachment time, consequently increasing cone productivity using any given of cone types. The maximum cone productivity of 1.663 and 1.236 tons/day was obtained at a cone rotary speed of 600 rpm for picking Washingtonia and Valencia oranges, respectively, using picking cone type IV. Increasing the cone rotational speed to more than 600 rpm for picking Washingtonia and Valencia oranges gave a decrease in cone productivity. The main reasons behind these results may be due to escape fruit from the picking cone by increasing its speed, which results in an increment in the number of trying times and the lost time to detect and detach the fruit from the tree, consequently, increasing the total fruit picking time and decreasing the labor productivity.

Also, providing the picking cone with an upper edge and internal rubber layer significantly affected the cone productivity as shown in **Fig. 7**. Using type II picking head (metal

Fig. 5 Average spacing between citrus trees and the tree dimensions

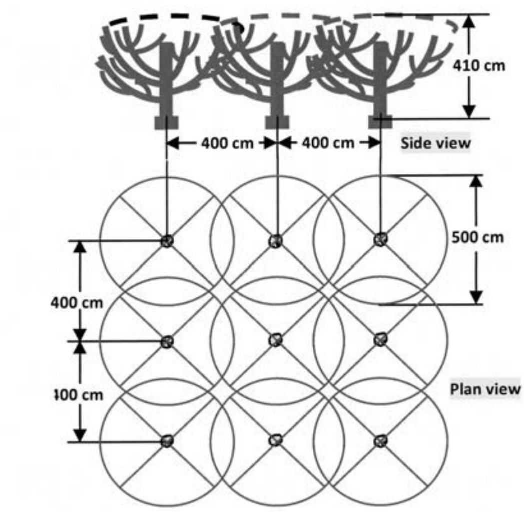


Fig. 6 Distribution percentage of fruit layers on the citrus trees canopy

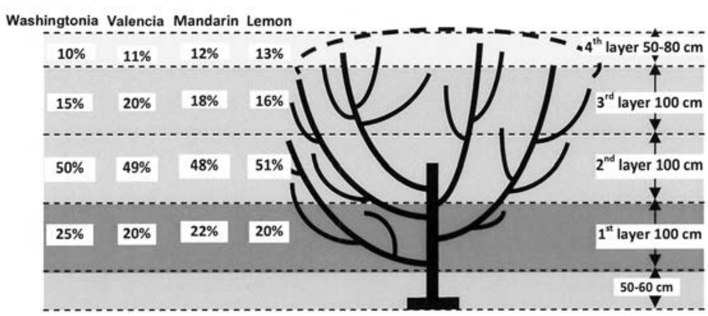
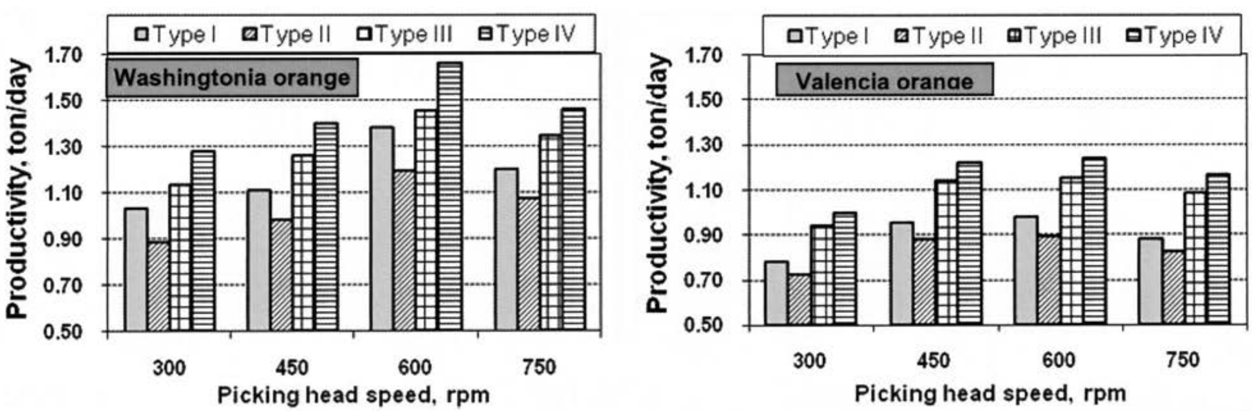


Fig. 7 Effect of using cone picking head on the labor productivity



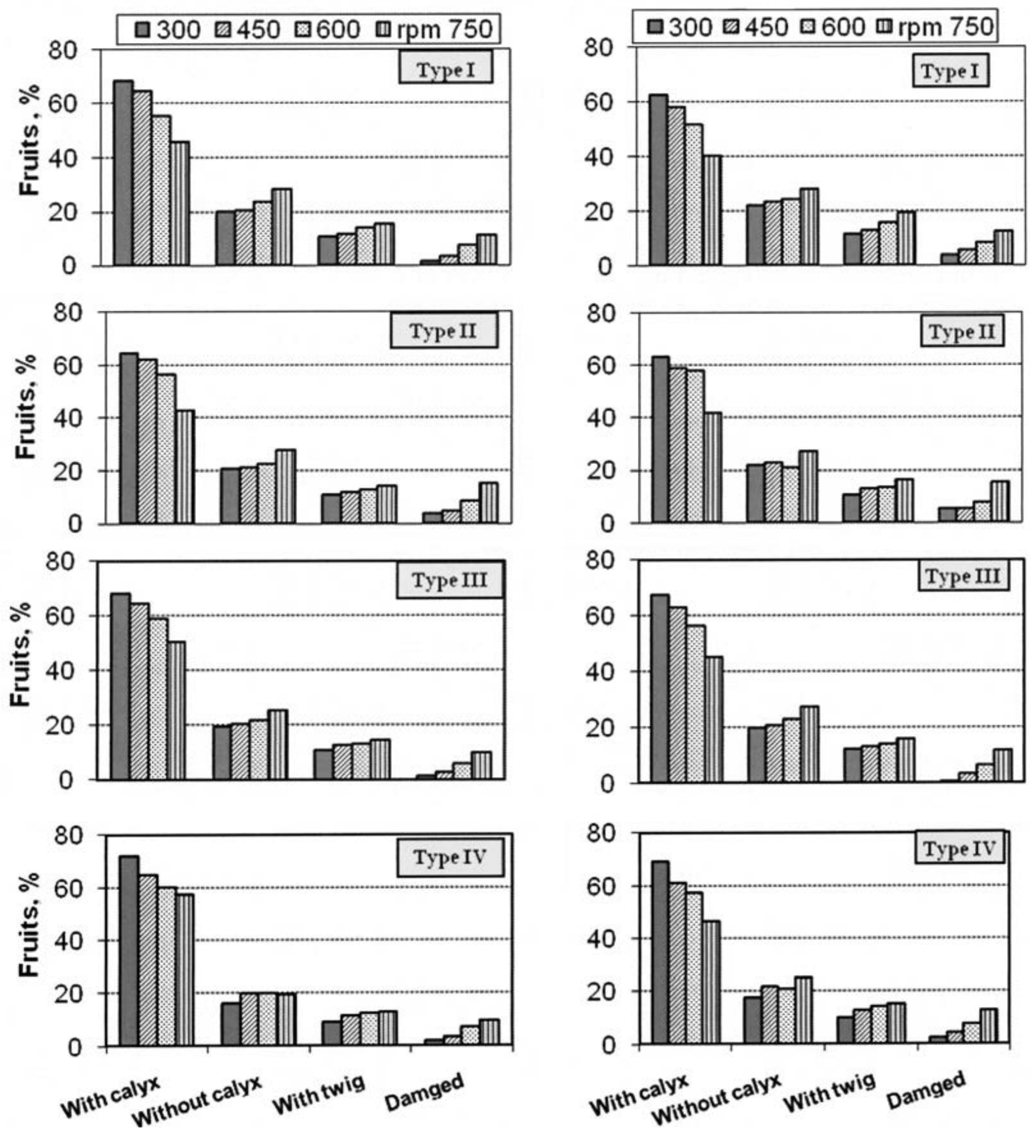
cone provided with an upper edge) gave the lowest values of labor productivity at any given rotating speed during picking Washingtonia and Valencia oranges. This results might have been due to some obstacles from the upper edge during detecting and detaching the fruit from the tree, in addition to the decreasing effect of the friction coefficient between cone inner surface and fruit surface. However, the highest value of productivity was obtained when using type IV picking head (cone provided with rubber inner surface and without upper edge) at any rotating speed compared with 0.890 and 0.671 ton/day using traditional methods for picking Washingtonia and Valencia oranges, respectively. These results may be due to increased effect of fruit detachment action by an increase in the friction of coefficient between cone inner surface and fruit surface, which decreased the detachment time and increased the productivity.

Fruit Quality:

The effect of using different types of rotary cone picking head and its rotating speeds on the picked fruit quality were measured, analyzed and illustrated in **Fig. 8**. From these results it could be concluded that the fruit quality was highly affected by the cone forms and rotating speeds, especially the percentage of damaged fruits (the percentage of dropped fruit out the fruit receiving tube and basket). This caused a decreased fruit quality and decreased its salable yield that had a major impact on the total picking cost.

The value of fruit without calyx percentage (Grade I) and with twig percentage (Grade II) were increased by increasing rotary cone speed during picking Washing-

Fig. 8 Effect of using cone picking head on the harvesting quality of Washingtonia (left) and Valencia (right) orange fruit



tonia and Valencia orange fruits. However, the value of fruit with calyx (Grade I) were decreased by increasing rotary cone speed. This result may be due to high torsional action occurred with high rotary speed. Also, the values of damaged fruit percentage (Grade IV, that fruit dropped out the receiving tube) was increased by increasing rotary cone speed during picking Washingtonia and Valencia orange fruits for all cone types under study. The highest values of damaged fruit percentage (15.26 and 15.31 %) were obtained by using picking cone type II at 750 rpm rotary cone speed. However, the lowest values (1.22 and 0.62 %) were obtained by using picking cone type III at 300 rpm rotary cone speed during picking Washingtonia and Valencia orange fruits, respectively.

The percentage of the fruit with calyx of 72.01 and 69.35 % (Grade I, extra fancy) represented the highest percentage obtained at any given cone type and rotary cone speed, followed by the percentage of fruits without calyx- Grade II (28.31 and 28.03 %) and percentage of fruit with twig- Grade III (15.27 and 19.16 %) during picking Washingtonia and Valencia orange fruits, respectively. The optimum fruit quality (the highest percentage of fruit with calyx-Grade I and lowest percentage of fruit Grades III and IV) was obtained by using picking cone type of metal covered by rubber layer on the inner surface and without upper edge (type III) in comparison with other picking cone types under study.

Performance Evaluation of the Electrical Scissors Picking Head

Electrical Scissors Productivity:

The prototype of electrical scissors picking head was evaluated using five different operators (pickers) for picking Washingtonia and Valencia oranges, Mandarin and Lemon fruits. The average productivity for different pickers is illustrated in **Fig. 9**. The highest productivity (1.224 tons/day) was obtained using electrical scissors for picking Valencia oranges followed by 1.029 tons/day when picking Washingtonia orange fruits. The productivity was decreased to 0.674 ton/day and 0.126 ton/day when using the electrical scissors for picking Mandarin and Lemon fruits comparing with picker productivity of 0.671, 0.890, 0.423 and 0.102 ton/day using traditional methods for picking Valencia and Washingtonia orange, Mandarin and Lemon fruits, respectively. This was in spite of the decreased the productivity of picking lemon fruits by using electrical scissors, but it was considered a good indicator for the productivity compared with the traditional picking method of lemons because of the difficulty of the hand picking of lemons due the barbs on the main and sub branches of the lemon tree, which directly affected the laborers hands during picking. Therefore, the traditional picking method used by farmers is shaking the tree or biting the tree bunches to drop the lemons on the ground. Meanwhile, the productivity of the scissors head was highly affected by the labor skill and fruit varieties.

Fig. 9 Effect of using electrical harvesting scissors on the labor productivity of citrus fruits

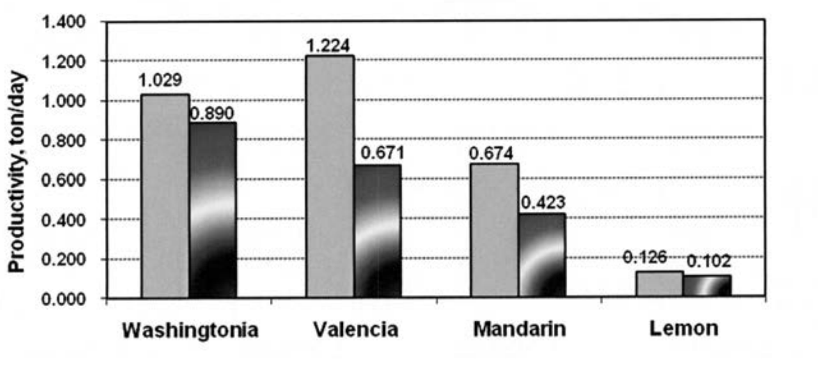
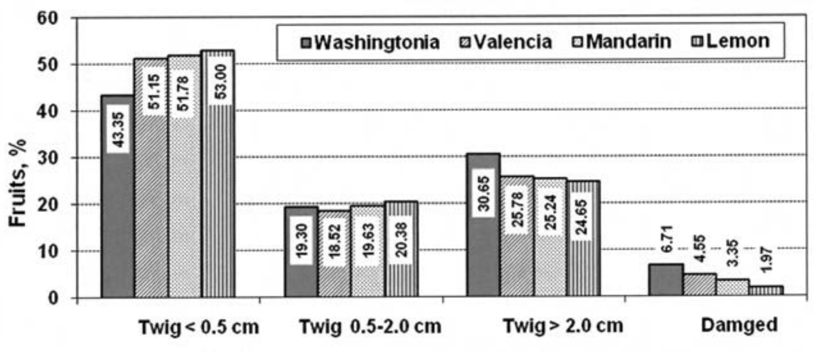


Fig. 10 Effect of using electrical harvesting scissors on the fruit quality



Picked Fruit Quality:

The effect of using electrical scissors head on the picked citrus quality was measured, and calculated for each citrus variety. The percentage of each grade is illustrated in **Fig. 10**. Percentage of grade I (< 0.5 cm twig length) was superior. The percentages were 43.35, 51.15, 51.78 and 53.00 % for picking Washingtonia and Valencia orange, Mandarin and Lemon fruits, respectively. On the other side, Damaged fruits percentages of 6.71, 4.55, 3.55 and1.97 % were found to be the lowest values for picking Washingtonia and Valencia orange, Mandarin and Lemon fruits, respectively.

Conclusion

The maximum cone productivity of 1.663 and 1.236 ton/day was obtained at cone rotary speed of 600 for picking Washingtonia and Valencia oranges, respectively, using picking cone form 4. On the other hand, increasing cone rotational speed more than 600 rpm for picking Washingtonia and Valencia orange fruits gave a decrease in cone productivity. The percentage values of the fruit with calyx of 72.01 and 69.35 % (Grade 1-extra fancy) represented the highest percentage obtained at any given cone form and rotary cone speed under study, followed by the percentage of fruits without calyx (28.31 and 28.03 %) and percentage of fruit with twig (15.27 and 19.16 %) during picking Washingtonia and Valencia orange fruits, respectively.

The highest productivity (1.224 tons/day) was obtained using electrical scissors for picking Valencia orange fruits followed by 1.029 tons/day when picking Washingtonia orange fruits. However, the productivity was decreased to 0.675 ton/day and 0.126 ton/day when using the electrical scissors for picking Mandarin and Lemon fruits. The percentage of grade I (< 0.5 cm twig length) was superior compared with the other two grades for all picked fruits. They were 43.35, 51.15, 51.78 and 53.00 % for Washingtonia and Valencia orange, Mandarin and Lemon fruits, respectively. On the other side, The damaged fruits percentages of 6.71, 4.55, 3.55 and 1.97 % were the lowest values for Washingtonia and Valencia orange, Mandarin and Lemon fruits, respectively.

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Introduction of Improved Equipment and Hand Tools for Farm Mechanization of Hilly Region in Indian Himalayas

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Abstract

In Indian Himalayas, topographic, technological infrastructure, credit and policy issues are major constraints. Farm machinery and power is an essential component in agriculture for timely field operations. Appropriate mechanization of hill agriculture is the need of the time and energy saving in various agricultural operations. Efficiency of human and animal energy was improved by designing better farm tools and machines that helped reduce drudgery of women farmers. This paper deals with the identification of the constraints in the use of traditional agricultural implements and small tools in the state of Uttarakhand hills. The level of mechanization in agriculture is low due to the traditional implements and hand tools used in agriculture operation. Improved agricultural equipment and tools have been introduced for efficient farm operation and drudgery reduction of hill farmers. Attempts are made to suggest various recommendations to overcome these problems.

Introduction

Uttarakhand is situated in North Western Himalayas of India located between 28º43’ N to 31º27’ N latitude 77º34’ E to 81º02’ E longitude. The state has an area 53,48,300 ha, which is 1.6% of the total geographical area of the country. About 70 % of the state are engaged in agriculture. A maximum part of the Uttarakhand state is hill area, i.e. 46,03,500 ha, and plain area is 7,44,800 ha. The average annual rainfall is 1,606 mm mostly received between the middle of June and end of September. Major crops are cereals; i.e. rice, wheat, barley, maize, millet and pulses; i.e. rajma, gahat, lentil and black gram.

Power is needed on the farm for operating different tools, implements and during various farm operations. While mobile power is used for doing different field jobs, the stationary power is used for lifting water and operating irrigation equipment, threshers, shellers/ decorticators, cleaners, graders and for other post harvest operations. The mobile farm power comes from human, draught animals, power tillers, tractors and self propelled machines; where as the stationary power is obtained from oil engines (diesel, petrol and kerosene) and electric motors.

Unlike in the plains, the green revolution has not made much impact in hilly areas. The reasons could be difficult terrain with undulating topography with small and scattered land holdings on steep slopes and lack of mechanization. Mechanization of agricultural operations in plains has played a vital role in efficient field operations thereby reducing the production cost. Whereas, Indian hill farming is almost untouched as far as mechanization is concerned (Singh, 2008).

Effective and efficient farm operations, resource conservation, protected cultivation and processing are some of the major aspects towards attaining viability of hill farming. In N.W. Himalayas, topographic, technological infrastructure, credit and policy issues are major constraints. Farming activities constitute a major livelihood to rural families. Hill agriculture is characterized by (1) terrain, climatic and natural resource constraints; (2) technology, skill and capacity constraints; and (3) infrastructure, remoteness, credit and policy constraints. The background of hill agriculture is reflected in poor productivity and resource degradation (Srivastva, 2006).

Traditional Farm Tools in Nwhr

In the hills, a number of traditional tools and equipment are used in farming but the efficiency is less because more time and labour is required to complete the farm operations. In villages for manufacturing of small tools, mostly wood is used like oak, sun, tun and falyant. The cutting of the wood is controlled and prohibited by the state government of Uttarakhand. The details are presented in **Table 1**.

Status of Farm Power

About 58 percent of the farmers in our country own less than 1 ha land whereas, in Uttarakhand, a large proportion of farmers (90 %) own less than 1 ha land. The need for a pair of bullocks can be well substituted by a suitable power tiller. Beyond that the power source should be a tractor for tillage, seeding, harvesting and an electric motor for agricultural operations. Ten percent of the Indian farmers, own around 50 % of the total cultivable land use tractor-operated implements.

Farm Mechanization

Farm mechanization has a positive relationship with farm productivity, firstly through timeliness of field operation and secondly, through good quality works (Khan, 1992). Energy and timeliness are crucial factors in sustaining higher productivity and economic viability of agriculture. Machines that are being used in the production of crops are constantly improving and changing. Developments in farm equipment technology have saved labour and time requirements. The energy consumption and time of hill crop production can be minimized by using improved hand tools and equipment. Therefore, for saving time, energy and for reducing drudgery of women, improved small tools designed and developed are given in **Table 2**.

The comparative time consumption and percentage of time saving by improved tools as compared to traditional tools and equipments given in **Table 3**.

Improved Small Hand Tools and Equipment for Hills

Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora, Uttarakhand, India has developed some improved Agriculture machinery and tools for reducing the drudgery of hill people which are given in following sections:

Improved Kutla

This hand tool is used for sowing and interculture operation. In tradi-

Table 1 Traditional farm tools used in North-West Himalaya

Equipment	Brief details	Operation	Remark
Kutla	Single iron bottoms, about 15 cm long, curved and fitted with 30 cm wooden handle.	Inter culture tillage in Kitchen garden and small plot.	Wooden handle.
Kassi	Heavy duty Kutla and shorter version of spade but heavier in weight.	Used for tilling stony and heavy soils.	Hill fields are generally stony with roots.
Garden rake	It has 8-10 iron spikes & wooden handle having 2-5 cm spacing, with different width of coverage.	Used for collection of grasses, leaves, stones and it is also used for breaking earth crust.	Ergonomics of the equipment may be improved for easy operation.
Khurpi	Single iron blade (15 × 5 cm), 15 cm long wooden handle.	Inter-culture, transplanting the vegetable seeds.	Long handle khurpi can be made for ease in operation.
Sickle	Sharp edge MS blade with wooden grip	Harvesting crops, lopping of thin branches, harvesting grasses for animal feeding	Improved darati with leaf steel blade may be may be used for same purposes.
Hand hoe	It has 8-10 iron spikes & wooden handle covering varying widths.	Used for collection of dried grasses, leaves, small stones or pebbles.	MS pipe handle with nut bolt may be used.
Ganesi/ chopper	Wood used for handle.	Used for chopping fodder for livestock feeding.	MS material and rubber handle may be used.
Spade	It has a longer handle of wood	Used for digging pits, tilling of wet land and making channels, etc.	In replace of wood handle MS pipe with rubber grip may be used.
Baryat	It has a longer handle of wood with heavy blade.	Used for lopping tree branches, cutting of throny bushes, slaughtering animals and for self defence.	In replace of wood handle MS pipe with rubber grip may be used.
Belcha	It has a longer handle of wood.	Used for shifting and loading the soil.	Wood can be replace with MS pipe with rubber grip.
Daav	Sharp edge blade with wooden grip.	Harvesting crops, lopping of thin branches, cutting of wood, slaughtering of animals and harvesting of grasses for animals feeding.	-do-

Table 2 Improvement in Farm Tools

Name of Hand Tools/Equipment	Use	Specific feature
Kutla	• Interculture • Weeding • Line making	• Rubber grip • Oil hardened share • MS Handle fixed with nut & bolt
Hand Fork	• Weeding • Interculture • Rubber Grip • MS Handle • Oil Quenching	
Garden Rake & Hand Hoe	• Leaf • Collection • Interculture	• Rubber Grip • MS Handle • Oil Quenching
Sickle (Darati)	• Cutting of grasses for fodder purpose • Harvesting field crops, • Cutting of this branches of tree	• Rubber Grip • Self Sharpening Blade • MS Handle
Khurpi (Small hand Hoe)	• Interculture • Vegetable Sowing	• Rubber grip • MS Handle • Heat treated using oil
Seed-cum ferti drill	• Sowing • Fertilizer Application	• Various power source can be used • Fertilizer applications in furrow
Millet Thresher	• Millet threshing & Pearling	• Use of canvas strip as cutting device • Easily replaceable sieve
Paddy Thresher	• Paddy threshing	• Pedal Operation • Operation in seating position

Table 3 Comparison of traditional and improved tools

Tool/ Equipment	Operation	Time required (h) Traditional tool	Time required (h) Improved tools	Time saving (%)
Kutla (small handle hoe)	Inter culture, h/ha	410	360	12.2
Garden Rake	Collection of grasses, h/ha	155	120	22.6
Hand hoe	Inter culture, h/ha	234	213	9
Khurpi	Inter culture, h/ha	480	467	2.7
Seed drill	Line sowing, h/ha	23	11	52.2
Millet thresher	Millet threshing, h/q	6	2.5	58.3
Paddy thresher	Paddy threshing, h/q	2.5	1	60
Winnower cum cleaner grader	Wheat cleaning, h/q	1	0.3	70

tional kutla handle is made of wood. Generally oak sun tree branches are used to make the handle of kutla. These trees are environmentally very-very important and come under reserve forest area. The cutting of these trees is prohibited. Keeping these points in view the handle of the kutla was made of mild steel pipe (MS pipe). For better grip and safety of operator a rubber grip has been provided on the iron handle of the kutla (**Fig. 1**). This rubber grip provides comfort in operation in winter season. The rake angle of the kutla share is kept between 30 to 60° for easy operation and less draft requirement. The weight, capacity and price of the kutla are 0.325 kg, 27.8 m^2/h and Rs.50 per unit, respectively. The length and diameter of the kutla handle are 310 and 18.5 mm, respectively. The rubber grip of 152.6 mm length and 32.5 mm diameter are also applied for easy operation. A comparative performance evaluation of the improved kutla was performed in field condition and found 12 % time saving as compared to the traditional kutla with the same share size.

Improved Garden Rake

The garden rake is used for collecting the grasses and stones of the ploughed field and leaves from the garden. Eight to ten spikes has been used in this rake. The provision of adjustable spacing has been made in this rake. This tool is used in a standing position. Therefore, a long handle is used for easy operation. In traditional rakes, a wooden

Fig. 1 Improved Kutla

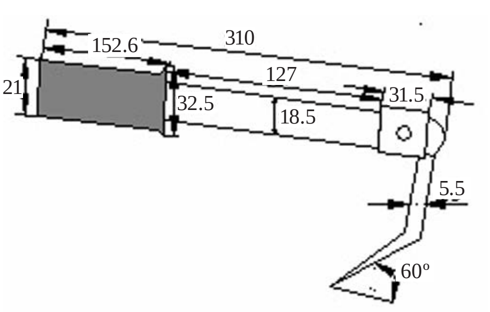
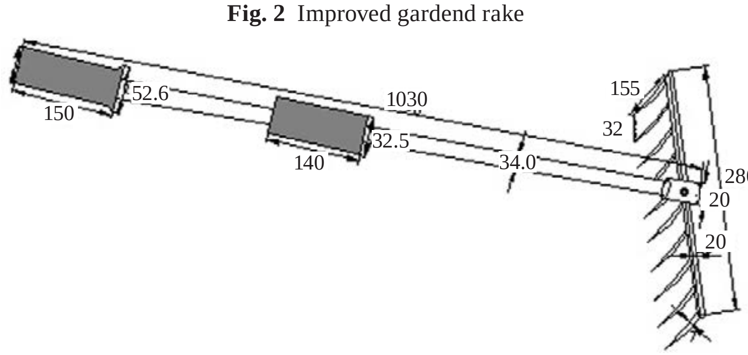


Fig. 2 Improved gardend rake



handle has been used. The width of coverage and spike spacing cannot be adjusted in traditional rakes. In the improved garden rake the handle has been made with MS pipe with two rubber grips (**Fig. 2**). The length and diameter of the handle and grip is 1,030 and 19 mm and 150 and 32.5 mm, respectively. The weight, field capacity and price of the improved garden rake are 1.25 kg, 83.3 m^2/h and Rs.150 per unit, respectively.

Improved Line Maker

This hand tool is used for making the lines for sowing of cereals and vegetable crop. Here also the wooden handle of tradition line maker has been replaced with an iron handle with rubber grip (**Fig. 3**). The weight, field capacity and price of this line maker are 4 kg, 1,000 m^2/h and Rs.250 per unit, respectively. The depth of coverage and spacing of the line maker can be adjusted as per need of the crop.

Improved Khurpi

This hand tool is used for intercultural operation and for transplanting the vegetable seeds. In traditional khurpi the grip has been made of wood. In the improved khurpi the wooden grip has been replaced with MS pipe covered with rubber grip (**Fig. 4**). The length of the khurpi is 300 mm and grip diameter is 33.5 mm. The length and width of the khurpi is 120 and 60 mm, respectively. The weight, capacity and price of the khurpi are 0.325 kg, 21.42 m^2/h and Rs.50 per unit, respectively.

Improved Hand Fork

This tool is used for weeding and interculture operation and can also be used for collecting the grasses of the pulverized fields. The length of the hand fork and grip is 300 mm and 150 mm, respectively (**Fig. 5**). Three L-shaped fingers with a spacing of 35 mm has been made of height 55 mm. The weight, capacity and price of the hand fork are 0.325 kg, 33 m^2/h and Rs.50 per unit, respectively.

Improved Sickle

This hand tool is used for cutting the grasses for fodder and lopping of thin branches of trees. The cutting blade of the sickle is made of high carbon leaf steel in which the sharpness of blade is kept maintained. A rubber grip of diameter 26.5 mm and length 150 mm has been fitted for ease in operation (**Fig. 6**). The length and weight of the sickle are 150 mm and 0.250 kg, respectively.

Improved Equipment

The equipment developed includes a seed drill, power operated zero till seed drill, lightweight power tiller, millet thresher-cum-pearler, paddy thresher and winnower cleaner-cum-grader (**Table 4**).

Vivek Mandua/Madira Thresher

Finger millet (Eleusine coracana) and barnyard millet (Echinochloa colona) are popularly known as mandua and madira, respecticely, in the hilly states of Uttaranchal. Mandua (or ragi) is grown over an area of 1,37,190 ha, while about 68,033 ha are under madira in the Uttaranchal state. Both these crops have relatively higher productivity in the state. A thresher was designed and developed (Singh *et al*., 2010) for the purpose of threshing and pearling grains of millets based on the grain properties (Singh *et al*., 2010 and 2011) of millet grains. It works on the principle of impact and

Fig. 3 Improved line maker

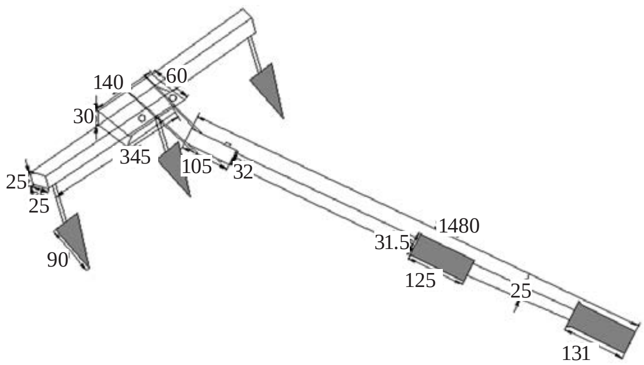


Fig. 7 Vivek millet thresher

Fig. 4 Improved khurpi

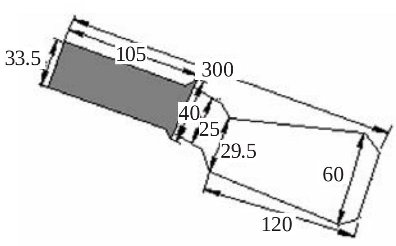


Fig. 5 Improved hand fork

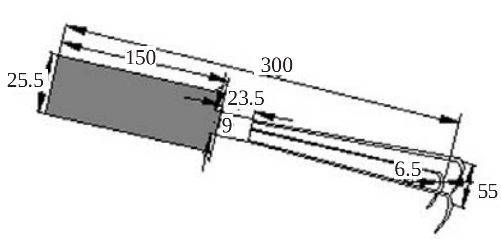
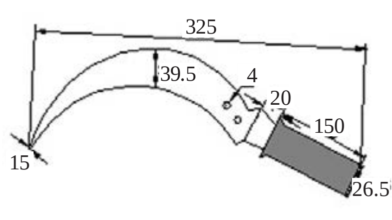


Fig. 6 Improved sickle



shear on the grain for the purpose of threshing, dehusking and pearling. The threshing drum is fitted with a canvas flat as a cutting device which provides a gentle impact and shear on the grain. The threshing chamber is fitted with a sliding door which is kept closed for specific period of time so as to allow repeatative impact and shearing to detach the hulk from the grain. It helps in complete threshing and dehusking of the mandua/madira. The sliding door is opened at a certain interval to take out the threshed materials (**Fig. 7**).

VL Seed-Cum-Fertilizer Drill

Unlike in the plains, the green revolution has not made much impact in hilly areas. The reasons could be difficult terrain with undulating topography with small and scattered land holdings on steep slopes and lack of mechanization. Mechanization of agricultural operations in plains has played a vital role in efficient field operations thereby reducing the production cost.

The productivity of major cereals in hills is much lower than the productivity of those crops observed in plains of Uttaranchal. This may be due to poor germination and population because of traditionally popular broad cast sowing in hills. Broadcast sowing not only requires more seed rate but also makes the intercultural operations cumbersome and labour intensive. Line sowing where seeding is done at appropriate depth gives 10-15 percent more grain yields than broadcast sowing across the crops.

Due to lack of a proper sowing device, the adoption of line sowing is almost negligible in hill farming. In hills, agriculture is performed on small zig zag terraces and farmers are resource poor. The bullocks available with the farmers are smaller in size and less in power than plain areas. Considering these points, efforts were made to develop a small compact and light weight seed drill (Singh *et al*., 2008) matching with the existing farming resources and situations. Farmers in the hills are generally poor and the higher production cost (almost all the agricultural operations are done manually) is a matter of concern. Therefore, during the seed drill development, the priority was whether the machine could be dual purpose; i.e. suitable for both ploughed (power source: 2 men) and un-ploughed (power source: 1 man and two bullocks) conditions and also has the provision to place the fertilizer at the proper place (**Fig. 8**).

Table 4 Farming operations and suitable farm equipments for hills

Agricultural operation	Suitable farm eqipments
Seed bed preparation	Modular Power tiller, Parvatiya hal
Sowing	Vivek Seed cum ferti-drill, Line sowing with the help of Kutla and line maker
Intercultural operation	Wheel hand hoe, Kutla, Khurpi
Harvesting	Serrated sickle, daranti and power tiller operated reaper
Threshing	Vivek millet thresher, VL muti crop thresher, VL paddy thresher
Cleaning and grading of cereals and pulses	Vivek winnower cleaner cum grader

Fig. 8 Vivek seed cum ferti drill (Bullock operated)

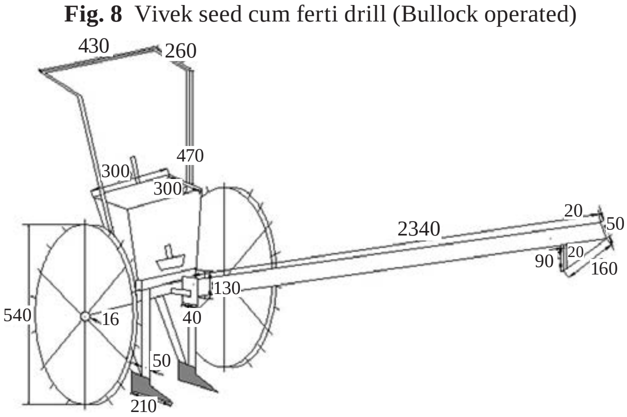


Fig. 9 Vivek seed cum ferti drill (Manual operated)

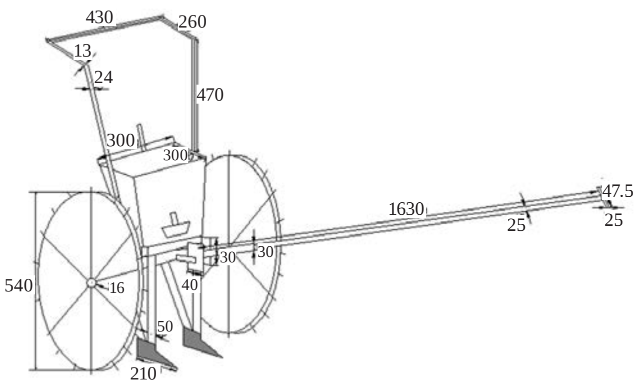
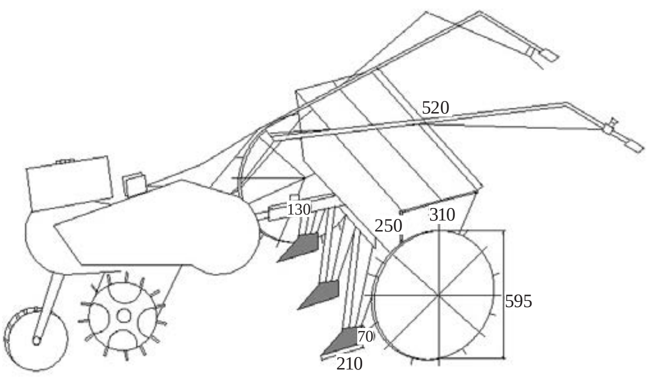


Fig. 10 Vivek seed cum ferti drill (Self propelled operated)



VL Paddy Thresher

VL Paddy Thresher was designed developed (Singh *et al*., 2008) for the purpose of threshing paddy grain. This is a manual-cum-power operated paddy threshing machine. It works on the principle of impact on the grain for the purpose of threshing. The threshing drum is fitted with a wire loop as a beating device, which provides impact on the grain. In this thresher, sitting arrangement has been made for the easy operation (**Fig. 9**). Chain-sprocket power transmission system with 1:7 speed ratio has been applied for providing rotational speed to the thresher. Threshing capacity and efficiency are largely affected by stem height, panicle height and 1,000 grain weight of paddy crop.

VL Winnower-Cum-Cleaner-Cum-Grader

A winnower-cum-cleaner-cum-grader suitable for winnowing, cleaning and grading of cereal, pulses crops in single pass. This machine has been designed and developed at Vivekananda Institute of Hill Agriculture, Almora, Uttarakhand. The machine was fabricated using locally available materials. It consists of a winnower, cleaning sieve and grading assembly. The total weight of the winnower cum cleaner cum grader is 60 kg. It can be operated by one person. The average cleaning efficiency of the machine for wheat is 95.63 %. The capacity of the machine is 300 kg/h. The overall efficiency of the machine is 97.5 % (**Figs. 12a** and **12b**).

Fig. 11 Manually operated Vivek paddy thresher

Suitable Farm Equipment for Hills

Adoption of the suitable farm equipment (**Table 4**) and practices depend on the economic status, education and the awareness of the farmers. In the hills of Uttarakhnad, around 20 % farmers own more than a hectare of land. Better quality of farm operations in less time can be done with suitable agricultural machinery and implements. Ample amounts of energy can be saved if appropriate farm equipment is made available for different farm operations because the economic progress of a state, as well as nation, directly depend upon the availability of energy and its consumption for a fruitful utilization.

Anthropometric Design Considerations for Improvement of Farm Tools in Hills

Anthropometric data are used in ergonomics to specify the physical dimensions of workspaces, equipment and furniture including clothing so as to "fit the task to the man", and to ensure that physical mismatches between the dimensions of equipment and user.

1) Standing eye height:

Height above the ground of the eye of a person standing erect can be used as a maximum allowable dimension to locate the visual displays.

2) Standing shoulder height:

Height of the acromion above the ground is used to estimate the height of the center of rotation of the arms above the ground for maximum allowable height of control.

3) Standing elbow height:

Height above the ground of the elbow of the person standing erect for maximum allowable equipment height.

4) Standing fingertip height:

Height of the tips of the fingers above the ground to determine the lowest allowable position for control.

5) Standing knuckle height:

Height of the knuckles above the ground to determine the minimum height of full grip.

6) Sitting height:

Fig. 12a Vivek winnower-cleaner cum grader for winnowing

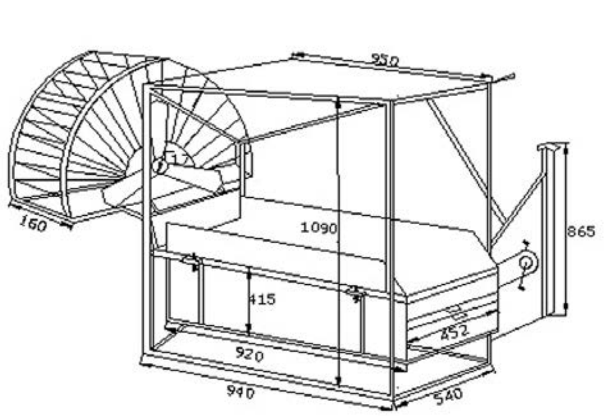
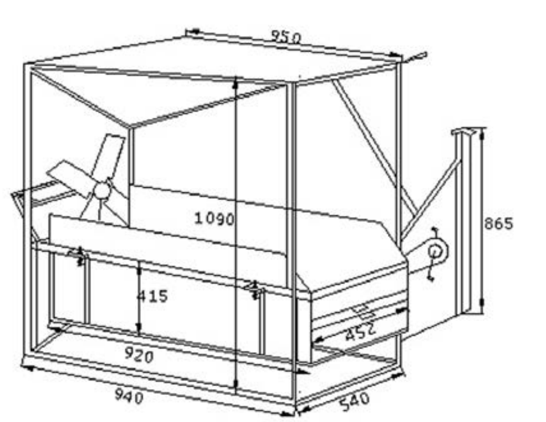


Fig. 12b Vivek winnower-cleaner cum grader for cleaning



Distance from the seat to the crown of the head to provide clearance to users with sitting height.

7) Shoulder width:

Widest distance across the shoulders to design handles of equipment; i.e. seeder.

8) Abdominal/Chest depth:

Widest distance from a wall behind the person to the chest/abdomen in front used for minimum clearance required.

9) Grip circumference:

Internal circumference of grip from the root of the fingers across the tip and to the palm when the person is grasping an object used to specify the maximum circumference of tool handles to hold in the palm of the hand.

Summary

Future improvements in hill agriculture will be energy dependent in addition to other factors. Mechanization of hill agriculture is still a new paradigm, which is attracting attention of many researchers in this field. These machines should be such that could be taken uphill or down the slope by two or three persons by lifting and carrying it physically. It must be able to operate in the narrow terraces and deep valleys where other bigger machinery are unable to reach and perform the operation. Mechanization of hill agriculture is the need of the hour for increasing the efficiency of various operations. The required machines should have more field performance than the manual tools and reduce the drudgery of operations. Efficiency of human and animal energy improved by designing better farm tools and machines that will help in reducing drudgery of women farmers. Farm mechanization will have to play a major role in making hill agriculture competitive and prosperous. Improved tools and implements will benefit in terms of enhanced efficiency and economy that will raise the profitability of the hill farming Success of mechanization depends on the degree of seriousness attached to the demonstrations, training and after sale services by different agencies, government policies and financial organizations. Use of improved tools may be a better option for hill farmers as compared to traditional tools since they can reduce farmer drudgery.

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Mechanization Practices in Rice-Wheat Cropping Systems in Upper Gangetic Plains of India

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Abstract

A three year field study was conducted on crop establishment and tillage options in rice-wheat cropping systems in sub-tropical India at Project Directorate for Cropping Systems Research, Modipuram, Meerut, U.P., (India) from 1999 to 2002. The treatment included three crop establishment practices (direct seeding, manual transplanting and mechanical transplanting by self-propelled rice transplanter) as the main plot in rice and three tillage levels (conventional, zero and strip) as the sub plot in wheat; replicated thrice. The highest mean grain yield of rice (6.11 Mg/ha) was obtained in mechanically transplanting that was, respectively, 27.3 and 50 percent higher than manual transplanting and direct seeding. In wheat, the highest mean yield (5.90 Mg/ha) was recorded under conventional sowing that was, respectively, 11.3 and 6.3 percent higher than zero and strip till drilling. The lowest mean weed dry weight (0.24 Mg/ha) was recorded under mechanical transplanting in rice and conventional tillage (0.19 Mg/ ha) in wheat. The greater root density in terms of root dry weight (7.5 gm /20 cm row length) was recorded in conventional tillage and the lowest root dry weight (5.8 gm / 20 cm row length) was obtained in zero tillage during 2000-01.The specific energy (392 kcal/ha) and benefit cost ratio maximum (3.25) in mechanical transplanting followed by manual translating and direct seeding of rice. In wheat, the zero till drilling required minimum specific energy (471 kcal/kg) followed by strip- till drilling (694 kcal/kg) and conventional sowing (501 kcal/kg). Soil physical parameters showed that infiltration rate and moisture content were significantly affected by both crop establishment and tillage practices, whereas bulk density was influenced by tillage practices during the three years. Significantly higher infiltration rate (1.50 cm/h) and moisture content (13.10 %) were recorded in direct seeding (puddled) adopted in the preceding rice crop, whereas lowest values of infiltration rate (0.69 cm/h) and moisture content (9.50 %) were obtained in zero tillage. The results show that mechanical transplanting by a self propelled rice transplanter in rice followed by strip till drilling (reduced tillage) in wheat resulted in higher productivity, profitability and energy saving in rice-wheat systems in India.

Introduction

Rice (Oryza sativa L.) —wheat (Triticum aestivum L) is one the major cropping systems of the Indian sub-continent (Majid *et al.*, 1988). This system covers about 12 million ha in India and is the backbone of food security with a yield potential of 8 Mg /ha /year (Singh *et al.*, 1986 and Bhandari *et al.*, 1992). Transplanting paddy is a labour intensive and arduous operation requiring 200-250 man-hours per hectare (about 25 % of the total labour requirement for the crop production) and results in low and non-uniform plant population and reduced crop yields. Moreover, the productivity is decreased due to want of proper equipment and labour. It calls for evaluation and popularization of the translating machine to cater to the needs of farmers (Singh and Gangwar, 1999).

Rice is normally transplanted in June-July in wet puddled soil. Puddling is essential for destruction of macropores (Jamison, 1953) and reduction in permeability (Bodman and Rubin, 1948). The reduction in permeability is highly desirable because it reduces the need for irrigation water. However, puddling results in poor physical conditions for the succeeding wheat crop. Under such conditions, 2-3 operations of primary tillage followed 2-3 operations of secondary tillage (in heavy soils even 8-12 operations) are commonly performed by farmers for seedbed preparation before sowing of wheat in November-December. Due to shortage of time after rice harvesting and wheat sowing, direct drilling of wheat is recommended.

Strip-till and zero-till drilling are partial conservation tillage systems because, whatever type of tillage is performed, it is not the same over the whole field (Anon, 1987 and Wiese, 1985). Conservation tillage systems reduce the production costs by requiring less labour, fuel, machinery and other inputs. However, highly reduced systems may require more pesticides and a higher management level to maintain or increase yield (Brown *et al*., 1989). The present study was, therefore, conducted to compare different tillage treatments in wheat after suitable crop establishment practices followed in rice under rice-wheat cropping systems.

Material and Methods

A field experiment was conducted for three years (1999-2000 to 2000-2002) at the experimental farm of Project Directorate for Cropping Systems Research Modipuram (29º4´ N latitude and 77º46´ E longitude), Meerut, U.P., India at an elevation of 237 m above mean sea level. The climate of Modipuram is broadly classified as semi-arid and sub-tropical. It is characterized by very hot summers and cold winters. The hottest months are May-June, when maximum temperatures may shoot up as high as 45-46 ºC, whereas, December and January are the coldest months of the year, when minimum temperature often goes below 5 ºC. The average annual rainfall is 862.7 mm, 75.80 percent of which is received through Northwest monsoon during July to September. The soil of the experimental field was sandy loam consisting of 642, 185 and 173 g/kg sand, silt and clay, respectively. According to FAO classification the soil was deep alluvial fine sandy mixed developed under hyperthermic regime (Typic Ustochrept). The soil pH, electrical conductivity, organic carbon, available P and available K as determined by procedures described by (Prasad 1998), respectively, were 8.02, 0.42 d s /m, 4 g/kg, 3.5 mg/kg and 36 mg/kg of soil.

Table 1 Puddled bed condition developed for rice transplanting

Parameters	Mean ± SD
Depth of puddled, mm	63.4 ± 4.3
Depth of water, mm	52.3 ± 2.6
Amount of dispersion, %	54.2 ± 6.2
Bulk density in 25-150 mm profile, Mg /m^3	1.37 ± 0.5
Water content in 25-150 mm profile, %	58.4 ± 5.8

Data represents average of 5 observations. SD = Standard deviation

Treatments

The field experiment was initiated during July 1998 with rice (Oryza sativa L.). The treatments consisted of three crop establishment practices, namely, direct seeding (puddled), manual transplanting and mechanical transplanting by self-propelled rice transplanter. Each method of puddled bed was prepared by dry tillage of two harrowing and two passes of the cultivator at 75-100 mm depth at a water content of about 20 %, followed by flooding for 24 hours and two passes of a rotary puddler. After 24 hours, the dispersed soil settled, the excess water drained to consolidate the soil and the soil was re-flooded with 25-50 mm of standing water just before start of the transplanting operation. The main plots were 50 m × 12 m while sub plots were 16 m × 4 m.

The puddled bed characteristics of soil prior to transplanting are given in **Table 1**. In direct seeding, pre-germinated seeds (soaked in water for 12 hours) were broadcast uniformly in the field at the rate of 50 kg/ha. For growing seedlings by the traditional method, pre-soaked seed (12 hours) were broadcast in the puddled bed at the rate of 35 kg/ha. Fertilizers were applied as per recommendation and water was applied as required. When the seedlings were 21 days old, they were uprooted and transplanted in the puddled field manually.

For mechanical transplanting, mat seedlings (50 m^2/ha of transplanting) were grown over 50 to 60 gauge polythene (10 % perforated) in the nursery bed (5 m × 1.2 m) with

side furrows. The soil was ground and sieved (2 mm) and mixed with farmyard manure (ratio of 3 : 1). The removing of the floating seeds, then disinfecting, soaking and sprouting the remainder prepared the seed at 25 kg/ha. Over the bed, 15 mm thick soil mixture was spread followed by uniformly spreading of sprouted seed and covered by 5 mm thick soil mixture. Then the jute bags or dry hay was placed over beds, if required, and water was sprinkled by the watering cane for 3-4 days. After that the jute bags/dry hay were removed and water was applied by flooding through side furrows. The seedlings became ready to transplant in 21 to 22 days when the highest reached 125-150 mm. The seedling mats were trimmed on sides and loaded into the transplanter (400 mates/ha of transplanting).

A self-propelled single wheel driven rice transplanter, (Chinese make, model: 2ZT-238-8) with a 2.4 kW air-cooled diesel engine and a transplanting system of fixed fork and knock out lever type planting fingers, was used for transplanting the mat seedlings. The machine covered 8-rows with 238 mm row spacing per pass.

After harvest of the rice crop, each of the plots was subdivided into three sub plots. The sowing of the wheat in winter season was done in sub plots using conventional method, zero-till drill and strip-till drill. In conventional tilled plots, two harrowing, two cultivating and one planking operation were performed and the sowing (HD 2,329) was done with seed cum fertilizer drill at the rate of 100 kg/ha. Sowing with zero and strip trill drill was done directly on the field without any soil preparation after harvest of rice. Each treatment was replicated thrice. The same seed rate, as well as fertilizer rate, was applied in the three sowing methods.

Crop Management

Rice (Oryza sativa L.) received 120 kg N as urea, 26 kg P as single super phosphate, 33 kg K as murite of potash and 25 kg Zn as zinc sulphate per ha. Nitrogen was applied in two doses; half at transplanting and the other half at panicle initiation. Wheat (Triticum aestivum L) received 120 kg N as urea, 26 kg P as single super phosphate and 33 kg K as murite of potash per ha. Rice and wheat were supplied with recommended doses of NPK; i.e. 120 kg N, 26 kg P and 33 kg K per ha. Nitrogen was applied in two applications, first half at sowing and the other half at first irrigation (21 days after sowing). Wheat received 4-5 irrigations and rice was irrigated as needed. Glyphosate (N-Phosphonomethilglycine) at 2.5 liter in 500-600 liter water per hectare was sprayed to kill green vegetation 20 days before of wheat sowing. Wheat was sown, in the third week of November, with respective seed drills on the same day to keep the same date of sowing, and harvested in the second week of April.

Soil and Plant Analysis

Soil moisture was determined gravimetrically (Jalota *et al*., 1998). After the third crop of wheat, the soil bulk density was measured in 0-15 cm depth by the core method (Blake and Hartge, 1996) and infiltration rate by infiltrometer (Bouwer, 1986). Root samples were collected from all plots with a core sampler of 5 cm inner diameter at 10 cm depth intervals from a single site (Garji *et al*., 1994) by centering the auger 3 cm away from the base of the plant. The length of the clean root samples was estimated by a line intercept method (Newman, 1986). The root samples were dried at 65 ºC for determination of their dry matter at 90 days after sowing. Weed spices and weed dry matter were recorded at 45 days after planting in rice and wheat from an area enclosed in quadrant of 0.25 m^2 randomly selected at two places in each plot. The weed samples were dried at 65 ºC for their dry matter.

Economic Methodology and Statistical Procedures

The economic and energy requirement for all the treatments were measured for the growing period of the crops. Labour, machinery, fuel, fertilizer, seed, pesticides and irrigations were considered as inputs for the growth period of the crops. The yield was considered as output of the crop. The economic and energy equivalent of the each parameter were calculated as per

Table 2 Rice grain yield (Mg ha^{-1}) affected by methods of planting

Planting method	1998-1999	1999-2000	2000-2001	Mean
Direct seeding (puddled)	3.40	4.30	4.50	4.07
Manual transplanting	4.50	5.10	5.40	5.00
Mechanical transplanting	5.10	6.50	6.80	6.11
$LSD_{0.05}$	0.66	0.54	0.60	-

Table 3 Wheat grain yield (Mg ha^{-1}) influenced by crop establishment and tillage practices

Tillage (in wheat)	Crop establishment (rice)												
	1999-2000				2000-2001				2001-2002				Overall mean
	DS	MT	Me T	Mean	DS	MT	Me T	Mean	DS	MT	Me T	Mean	
Conventional tillage	5.02	3.70	3.81	4.17	5.92	5.28	5.33	5.61	6.32	5.68	5.71	5.90	5.23
Strip tillage	3.83	2.98	3.42	3.41	5.73	5.32	5.58	5.45	6.03	5.62	5.88	5.82	4.89
Zero tillage	3.20	2.87	3.06	3.04	5.80	5.13	5.25	5.39	5.70	5.33	5.45	5.40	4.61
Mean	4.02	3.18	3.43		5.82	5.24	5.39		6.02	5.54	5.68	-	-
$LSD_{0.05}$													
Crop establishment	0.40				0.36				0.42				
Tillage	0.56				0.16				0.61				
Tillage × Crop establishment	0.90				0.27				0.82				
Crop establishment × Tillage	0.89				0.42				0.70				

DS, Direct seeding; MT, manual transplanting; MeT, mechanical transplanting; CT, conventional tillage; ST, strip tillage; ZT, zero tillage the procedure given by Pimental (1980). The data were subjected to analysis of variance for a split plot design with the method of rice planting in main plots and wheat planting in sub plots as procedure given by Little and Hills (1978). The treatment effects were tested by the "F test". The significant differences between treatments were compared by standard error of differences at 5 percent levels of probability.

Results

Grain Yield

The rice yield was significantly affected by methods of planting. The greater mean grain yield of 6.11 Mg/ha was for mechanical transplanting (by self-propelled rice transplanter) followed by manual transplanting and direct seeding (**Table 2**). The growth and subsequent establishment of transplanting seedlings by self-propelled rice transplanter were faster with almost no loss of plants giving significantly higher number of yield attributes. Apart from this, the uniform growth of the crop was also observed due to uniform spacing and depth of placement of seedlings with equal number of seedlings per hill. These factors contributed to higher grain yield of rice under mechanical transplanting.

The wheat yield was significantly affected by different planting methods of both rice and wheat during all the three years of experimentation (**Table 3**). Direct seeding adopted in preceding rice crop produced significantly higher three-year mean wheat yield (5.29 Mg ha^{-1}) compared to mechanical (4.83 Mg ha^{-1}) and manual transplanting (4.65 Mg ha^{-1}) methods. Variation in wheat yield between manual and mechanical transplanting was not significant. Among tillage practices used for sowing wheat, significantly greater overall mean wheat yield (5.23 Mg ha^{-1}) was obtained under conventional tillage followed by reduced tillage (4.88 Mg ha^{-1}) and zero tillage (4.61 Mg ha^{-1}) treatments. Better germination and low weed infestation resulted in higher value of yield contributing characters; i.e. ear head/m^2 grain/ear head, length of ear head and 1,000 grain weight (**Table 4**) that ultimately contributed to higher yield of wheat.

Interaction effect between tillage levels with in crop establishment practice and also between crop establishments practices within a tillage level were significant. The highest mean grain yield (5.75 Mg ha^{-1}) was obtained in conventional tillage where direct seeding was done in the preceding rice crop while lowest mean grain yield (4.44 Mg ha^{-1}) was recorded under zero tillage and manual transplanting.

Weed Dynamics

In order to study the weed competition under different methods of planting, weed species and weed dry matter were recorded at 45 days after planting of rice and wheat. However, weed count were not taken in any of the crop. Among the major weeds, Enchinochloa crusgalli (barnyard grass) was the most predominant weed affecting the rice crop followed by Cyperus iria (nutgrass) while other species were of minor significance in rice. The direct seeding recorded highest weed dry weight (0.14 Mg ha^{-1})

Table 5 Weed dry weight Mg ha^{-1}) in rice at 45 days after planting as influenced by methods of planting

Planting method	Weed dry weight			
	1998-1999	1999-2000	2000-2001	Mean
Direct seeding	0.14	0.14	0.12	0.13
Manual transplanting	0.12	0.12	0.11	0.11
Mechanical transplanting	0.025	0.032	0.014	0.024
$LSD_{0.05}$	0.025	0.017	0.015	-

Table 4 Yield attributes of wheat as influenced by crop establishment and tillage practices

Treatment	1999-2000				2000-2001				2001-2002			
	Ear head m^{-2}	Grain ear $head^{-1}$	Length of ear head, cm	1000-grain weight, g	Ear head m^{-2}	Grain ear $head^{-1}$	Length of ear head, cm	1000-grain weight, g	Ear head m^{-2}	Grain ear $head^{-1}$	Length of ear head, cm	1000-grain weight, g
Crop establishment (in rice)												
Direct seeding	284	36.7	8.7	39.0	333	41.6	10.7	41.6	354	42.5	10.8	42.7
Manual transplanting	276	31.6	7.6	38.3	305	36.5	9.6	41.5	321	37.7	9.7	41.5
Mechanical transplanting	291	34.8	8.1	38.8	297	39.8	10.1	41.1	301	40.8	10.2	40.3
$LSD_{0.05}$	NS	2.3	0.45	0.54	18.5	3.1	0.40	0.89	20.6	2.9	0.3	1.8
Tillage (in wheat)												
Conventional tillage	322	34.5	8.5	39.0	308	39.5	10.5	41.4	312	41.1	10.6	42.7
Strip tillage	273	34.3	8.0	38.6	321	39.3	10.1	41.9	331	41.2	10.2	41.5
Zero tillage	256	34.3	8.0	38.5	306	39.3	10.0	41.0	310	41.1	9.9	41.1
$LSD_{0.05}$	0.9	NS*	NS	0.38	16.3	NS	0.43	0.57	15.2	NS	0.5	1.1

*NS = Non significant

during first two years and lowest in the third year (0.12 Mg ha^{-1}), compared to manual and mechanical transplanted. The lowest dry weight of weeds (0.025 Mg ha^{-1}) was noticed in mechanical transplanting (**Table 5**). In wheat, the majority of weeds were Phalaris minor (wild canary-grass), Angallis arvensis (blue pimpernel), Cyperus rotundus (nutsedge), Cornopus didimus (swinecress), Chenopodium album (common lambsquarters), Melilotus indica (sweet clover), Visia sativa(common vetch) and Lathyrus aphca (yellow vetch). Among these species, Phalaris minor was the most prominent weed infesting the wheat crop. Weed dry weight showed the perceptible influence of crop establishment and tillage practices. Significantly lower dry weight of weeds (0.19 Mg ha^{-1}) was recorded with mechanical transplanting. Similarly, conventional tillage also had lowest mean weed dry weight (0.19 Mg ha^{-1}) followed by reduced tillage and zero tillage (0.26 Mg ha^{-1}) because zero tillage practices avoid burial of weed seed and preserve them in the soil (**Table 6**).

Root Density

Root density in terms of root length and root dry weight was significantly affected due to tillage practices only (**Table 7**). Conventional tillage resulted in greater mean root length (22.2 cm) and higher root mean dry weight (7.4 g) as 20 cm row length compared to reduce and zero tillage due to more compaction of soil that, in turn, restricted root length. Crop establishment practices followed in rice did not bring significant variation in root length and root dry weight of wheat. However, numerically, more root length and dry weight was observed with direct seeding.

Energy Use

The operational energy, energy output, specific energy, energy output-input ratio, grain yield, cost of production, net income and benefit-cost ratio for direct seeding, manual and mechanical transplanting of rice are given in **Table 8**. The mechanical transplanting required minimum specific energy (392 kcal ha^{-1}) than manual transplanting of rice (487 kcal ha^{-1}) and direct seeding of rice (573 kcal ha^{-1}). The benefit-cost ratio of mechanical transplanting was maximum (3.25) followed by manual (2.44) and direct seeding (2.37). In wheat, strip-till drilling required minimum specific energy of 458 kcal kg^{-1} followed by zero-till drilling (471 kcal kg^{-1}) and conventional sowing (501 kcal kg^{-1}). However, the energy out put-input ratio of conventional sowing was maximum (4.88) followed by strip-till drill (4.32) and zero-till (3.91) drilling (**Table 9**). Thus, mechanical transplanting of rice followed by strip-till drilling of wheat in rice-wheat system was most energy efficient.

Changes in Soil Physical Properties

Crop establishment and tillage practices significantly affected infiltration rate, bulk density and mois-

Table 6 Weed dry weight (Mg ha^{-1}) in wheat at 45 days after planting as influenced by crop establishment and tillage practices

Planting method	Weed dry weight			Mean
	1998-1999	1999-2000	2000-2001	
Crop establish-ment (in rice)				
Direct seeding	0.22	0.25	0.26	0.24
Manual transplanting	0.20	0.23	0.25	0.23
Mechanical transplanting	0.19	0.21	0.22	0.21
$LSD_{0.05}$	0.047	0.043	0.056	
Tillage (in wheat)				
Conventional tillage	0.17	0.19	0.20	0.19
Strip tillage	0.21	0.23	0.25	0.23
Zero tillage	0.23	0.27	0.28	0.26
$LSD_{0.05}$	0.046	0.015	0.012	-

Table 7 Wheat root length and dry weight as influenced by crop establishment and tillage practices (at 90 days after planting)

	1999-2000		2000-2001		2001-2002		Mean	
	Root length, cm	Root dry weight (g 20 cm row^{-1})	Root length, cm	Root dry weight (g 20 cm row^{-1})	Root length, cm	Root dry weight (g 20 cm row^{-1})	Root length, cm	Root dry weight (g 20 cm row^{-1})
Crop establishment (in rice)								
Direct seeding	18.2	6.5	18.3	6.6	18.6	7.0	18.3	6.7
Manual transplanting	17.2	6.2	17.5	6.3	17.8	6.5	17.5	6.3
Mechanical transplanting	16.7	5.9	17.0	6.0	17.0	5.6	16.9	5.8
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS		
Tillage (in wheat)								
Conventional tillage	22.3	7.3	22.3	7.5	22.0	7.5	22.2	7.4
Strip tillage	18.5	6.4	18.8	6.6	18.2	6.4	18.5	6.5
Zero tillage	15.7	5.9	16.0	6.0	14.9	5.8	15.5	5.9
$LSD_{0.05}$	1.8	0.7	1.8	0.7	1.7	0.6	-	-

ture content (**Table 10**). The higher mean infiltration rate (1.47 cm h^{-1}) and mean moisture content (12.90 %) were recorded in direct seeded and lower mean infiltration rate (1.36 cm/h) and mean moisture content (11.30 %) were noticed under mechanical transplanting adopted in preceding crop of rice. Bulk density was not affected significantly by crop establishment practices. However, a minimum mean value of bulk density (1.59 Mg m^{-3}) was registered in direct seeding followed by mechanical transplanting adopted in rice crop (1.62 Mg m^{-3}). The different tillage operations were found to make spectacular changes in soil physical properties and higher mean infiltration rate (1.35 cm h^{-1}) was observed in conventional tillage, which clearly revealed the quality of field preparation that allowed more water to penetrate in the field and in turn helped the wheat crop to grow vigorously. The lowest mean infiltration rate was recorded in zero tillage due to compaction of soil. The mean bulk density was lowest (1.59 Mg m^{-3}) in conventional tillage and minimum in zero tillage (1.68 Mg m^{-3}). The highest mean moisture content (12.91 %) was with conventional tillage followed by reduced (12.31 %) and zero tillage (9.73 %) treatments.

Table 8 Economics and energy use in direct seeded, manually and mechanically transplanting rice

Parameters	Direct seeding Mean + SD	Manual transplanting Mean + SD	Mechanical transplanting Mean + SD
Cost of production, US \$ ha^{-1}	217 +1.30	250 +1.10	239 +1.50
Net income, US \$ ha^{-1}	297 +1.95	262 +2.50	538 +2.30
Benefit: cost ratio	2.37 +0.22	2.05 +2.30	3.25 +0.28
Specific energy, Kcal kg^{-1}	573 +2.95	487 +2.50	392 +2.62
Energy output: input ratio	5.2 +0.26	6.2 +0.21	7.7 +0.18

Data represents average of 3 years

Table 9 Economics and energy use in strip and zero till drilling with conventional sowing of wheat after harvest of rice

Parameters	Conventional sowing	Strip till drilling	Zero till drilling
Cost of production, US \$ ha^{-1}	261	213	202
Net income, US \$ ha^{-1}	620	695	671
Benefit: cost ratio	3.38	4.26	4.32
Specific energy, Kcal kg^{-1}	501	458	471
Energy output: input ratio	4.88	4.32	3.91

Data represents average of 3 years

Table 10 Influence of different crop establishment and tillage practices on physical properties of soil after harvest of wheat crop

Treatment	Infiltration rate (cm h^{-1})				Bulk density (Mg m^{-3})				Moisture content (%)			
	1999-2000	2000-2001	2001-2002	Mean	1999-2000	2000-2001	2001-2002	Mean	1999-2000	2000-2001	2001-2002	Mean
Crop establishment (in rice)												
Direct seeding	1.50	1.48	1.42	1.47	1.58	1.60	1.60	1.59	12.7	12.9	13.1	12.9
Manual transplanting	1.44	1.40	1.37	1.40	1.60	1.61	1.62	1.61	12.2	12.3	12.6	12.4
Mechanical transplanting	1.39	1.36	1.32	1.36	1.61	1.62	1.63	1.62	11.5	11.2	11.2	11.3
$LSD_{0.05}$	0.10	0.09	0.07		NS	NS	NS		1.1	1.5	1.8	
Tillage (in wheat)												
Conventional tillage	1.40	1.35	1.30	1.35	1.54	1.60	1.62	1.59	12.3	13.2	13.3	12.9
Strip tillage	1.25	1.20	1.18	1.21	1.67	1.67	1.65	1.66	11.6	12.6	12.7	12.3
Zero tillage	0.90	0.80	0.69	0.80	1.69	1.69	1.66	1.68	9.5	9.7	10.0	9.7
$LSD_{0.05}$	0.40	0.35	0.70		0.70	0.12	0.12	0.03	2.4	2.8	3.1	-

Discussion

Consistently higher yield of rice was recorded in mechanical transplanting (by self propelled rice transplanter). This was significantly greater than manual transplanting and direct seeding (unpuddled) due to crop growth and subsequent establishment of transplanted seeding by self-propelled rice transplanter. This was, also, faster with almost no loss of plants giving a significantly higher number of yield attributes such as effective tiller m^{-2}, panicle length (cm), panicle weight (g), number of filled grains panicle-1 and 1,000 grain weight (g). Besides this, uniform growth of crop was also observed due to uniform spacing and depth of seed placement with an equal number seedlings per hill. These factors contributed to higher yield of rice under mechanical transplanting (Singh and Gangwar, 1999). The reduction in yield was on the order of 6.7 % and 11.9 % under reduced and zero tillage treatments, respectively. This higher yield under conventional tillage was probably due to better germination and adequately low weed infestation. Singh *et al.* (1998) also reported that wheat sown after conventional tillage resulted in taller plants, longer and bolder ears, more grains ear-1 and higher grain yield compared to wheat sown with zero and reduced tillage. Adoption of direct seeding in the rice crop proceeding wheat produced a higher overall mean wheat yield compared with manual and mechanical transplanting. This was mainly attributable to relatively greater compaction of puddled soil under mechanical transplanting and its carry-over effect of succeeding wheat. In direct seeded rice plots the subsequent wheat yield was highest and demonstrated the disadvantages of puddling and transplanting on succeeding wheat crops (Tripathi *et al*., 1999). Among tillage levels, conventional tillage produced significantly greater yield of wheat and reduced tillage and zero tillage produced 5.9 and 13.4 % less, respectively. Taller plants, heavier ears and more grains per ear were observed in conventional tillage than with zero tillage. Similar result were reported by Oussible and Crookston (1987) and Singh and Brar (1994).

Growth parameters including root growth and dry matter accumulation were affected significantly by tillage under different methods of rice seeding. Wheat plants grown in conventional tillage had nearly 30 % higher root dry weights than plants grown in zero tillage, probably related to finer seed bed preparation. The lowest root dry weight was observed in zero tillage and probably related to compaction of the soil. Immediately after rice cropping, aerobic soil conditions, impaired soil structure and a hard pan are major impediments to the establishment and growth of wheat (Meelu *et al*., 1979; Kirchhog and So, 1996).

The destruction of soil aggregates by puddling leads to the formation of surface crusts and cracks on drying, delaying preparation of the seedbed for the wheat crop. When broken by tillage, the resulting large clods provide poor contact with seed, thereby restricting germination. Subsurface compaction caused by puddling generally reduces root growth of wheat (Oussible *et al*., 1992; Aggarwal *et al*., 1995), although roots that penetrate the compacted layer before it hardens on drying may extend more deeply as soil drains (Sur *et al*., 1981). Very little (Little *et al*., 1978) is known of the root growth of wheat in rice-wheat systems on puddled soils of heavy texture. Tayer *et al.* (1966) observed that the rate of root elongation is inversely related to soil strength. Greater mechanical impedance encountered by axially elongating the root causes thickening of root tips (Russell and Goss, 1974) but sub soiling of sandy soil reduces root thickening as indicated by increases in root length to mass ratios (Prihar and Gajri, 1994).

Crop establishment methods in rice and tillage in wheat significantly influenced weed flora and their dry matter production of (**Tables 4** and **5**). Mechanical transplanting recorded lowest weed dry matter since almost weed-free seedlings were grown and planted by self propelled rice transplanter as compared to manual transplanting and direct seeding (Singh and Gangwar, 1999). Similarly, Reddy and Hukkari (1980a) reported an improvement in rice yield due to fewer weeds under puddled conditions. Significantly, lowest weed dry weight was obtained under mechanical transplanting adopted in previous rice crop due to good growth of wheat in this treatment that had a smothering effect on weed population. In the same way, conventional tillage recorded lowest dry weight followed by reduced and zero tillage because zero tillage avoided burying weed seeds and preserved them in the soil. Weed seed germinate in large numbers when they get a congenial environment and offer heavy weed competition in wheat crop (Pandey *et al*., 2005). The specific energy in mechanical transplanting in rice and zero tillage in wheat was minimum as compared to the other treatments. It was due to a minimum requirement of input energy (Singh and Gangwar, 1999).

The higher infiltration rate and soil moisture content were recorded under direct seeding while low values were obtained in mechanical transplanting adopted in preceding rice crop because of puddling surface soil. Tillage operations resulted in higher infiltration rate and moisture content of the soil as compared to zero tillage. This might be attributed to pulverized soil conditions due to loosening of the soil mass under conventional tillage (Singh *et al*., 1998). Tillage significantly decreased soil bulk density since settling of soil particles can increase bulk density under zero tillage systems (Cassel and Nelson, 1985).

Conclusions

Under rice-wheat sequence, in rice, the mechanical transplanting (by self-propelled transplanter) provided considerable savings in time, cost of production, energy use and increase in productivity and profitability compared to manual transplanting and direct seeding. In wheat, strip and zero till drilling were more cost and energy efficient compared to conventional tillage. Further, mechanical transplanting resulted in lower weed density and weed dry weight in comparison to direct seeding and manual transplanting due to churning of puddled soil. Similarly, mechanical transplanting adopted in rice resulted in lower weed density and weed dry weight in wheat. The zero till drilling decreased Phalaris minor population compared to conventional sowing in wheat. The conventional tillage improved the soil physical environment to favor root growth, increase infiltration rate and moisture content and decrease the bulk density. Therefore, mechanical transplanting in rice followed by conventional sowing or strip-till drilling in wheat recorded higher productivity and profitability in the rice-wheat system.

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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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Synergic Effect of Heat Treatment and Peening Intensity on Low Stress Abrasive Wear Behaviour of High Strength Low Alloy Agricultural Grade Medium Carbon Steel: **Dushyant Singh**, Central Institute of Agricultural Engineering, Bhopal-462038, INDIA; **D. P. Mondal**, Advanced Materials and Processes Research Institute, Bhopal-462026, same; **S. Rathod**, same; **N. V. Prasad**, Central Institute of Agricultural Engineering, Bhopal-462038, same.

The performance and efficiency of soil engaging agricultural machines like cultivator sweep, furrow opener of seed drills and planters depends on their mechanical properties and abrasive wear resistance. It is seen that in agricultural field more than 50 % of wear is abrasive in nature. To study the wear rate of low alloy medium carbon steel (commonly used in agriculture), three body abrasive wear (low stress abrasive wear) tests were conducted. In order to achieve different types of microstructures and mechanical properties, the medium carbon steel was heat-treated differently. Steels were further subjected to shot peening in the range of 0.17 to 0.47 mm ALMEN 'A' to improve their surface properties. It was noted that the intercritically annealed and quenched and tempered steels showed comparable wear rate. The wear rates of inter critical annealed and quenched and tempered steels are considerably less than that of as-received and annealed steels, irrespective of peening intensity. It could be further noted that the steels exhibit the minimum wear rate at a critical peening intensity of 0.17 mm ALMEN'A' irrespective of heat treatment schedules.

■■

Evaporative Cooling Chambers using Alternative Materials

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Abstract

Two evaporative cooling chambers (ECC) were constructed with baked bricks. One of the evaporative cooling chambers was filled with river bed sand and the other with rice husk ash (RHA). The rice husk ash was used as alternative material due to its higher water retention capacity as compared to river bed sand. Temperature and relative humidity were recorded inside and outside the evaporative cooling chambers for round the year use. In summer and winter seasons the average dry bulb temperature in the evaporative cooling chamber with river bed sand was 9.6 ºC and 4.6 ºC lower than ambient and with rice husk ash it was 11.9 ºC and 5.5 ºC, respectively. The average relative humidity was 56 % and 45 % higher than ambient in summer and winter for ECC RBS whereas in ECC RHA was 61 % and 50 %, respectively. The average cooling efficiency for summer with ECC RHA was 16 % higher than with ECC RBS and for winter was 8 %, respectively. Thus, the shelf life of the fruits and vegetables kept in these chambers cobe increased substantially all year.

Introduction

Fruits and vegetables constitute a commercially important and nutritionally indispensable food commodity. The post harvest losses in fruits and vegetables are due to lack of harvesting machinery, non-availability of collection centers, inadequate transportation network, lack of proper packaging systems, cold storage facilities and processing centers. Storage at low temperature, after harvesting reduces the rate of respiration resulting in reducing respiration heat, thermal decomposition and microbial spoilage and also helps in retention of quality and freshness of the stored material for a longer period (Chopra *et al.*, 2003). The farmers usually face difficulty disposing of their produce in summer when the produce spoils quickly because of the extremities in temperature coupled with low relative humidity. During that period, the power crisis often remains at its peak. For each 10 ºC increment above optimum temperature the rate of spoilage increases by 2 to 3 fold (Jimenez, 1983).

Evaporative cooling is an efficient, economical, environmentally friendly and healthy means of reducing the temperature and increasing the relative humidity in an enclosure and has been extensively tried for increasing the shelf life of horticultural produce. Evaporation of water produces a considerable cooling effect and as evaporation increases so does the cooling effect (Esmay and Dixon, 1986). The low-cost evaporative cooling chambers (zero energy cooling chambers) are reported to enhance shelf life of fruits and vegetables by lowering the temperature and maintaining high humidity inside the chamber. The cooling chamber can reduce the temperature by as much as 17 ºC to 18 ºC during peak summer months and maintain a humidity of about 90 % throughout the year. The low cost of this cooling system makes it especially suitable for short-term farm storage (Roy and Khurdiya, 1986). The low temperature by an evaporative cooling system is also beneficial for pre-cooling of horticultural produce before and during transit. Evaporative cooling structures can be used for short term on-farm storage of fresh produce so that the farmer can extend the shelf life of the commodities by 2 to 5 fold (Maini and Anand, 1992; Khurdiya, 1995). The evaporative cooling structures need not be commodity specific and can be used for storage of any produce that can withstand the temperature and relative humidity ranges. Alternative materials for the evaporative cooling structures and proper operational schedule may be investigated to offer a better economic picture for this type of structure.

Keeping in view the present energy crisis and inadequate availability of cold storage, particularly in the developing countries like India, attempts have been made to develop low cost evaporative cooling chambers (ECC) using alternative materials like river bed sand (RBS) and rice husk ash (RHA) which can be adopted easily by farmers without using any electrical or mechanical energy.

Materials and Methods

Development of Evaporative Cooling Chambers

Two evaporative cooling chambers of 0.37 m^3 capacity each were constructed with baked bricks. Dimensions of the evaporative cooling chambers are presented in **Table 1**. Two platforms of 1.65 m × 1.15 m were prepared with a single layer of bricks cemented from the top to prevent water seepage into the soil. A double layered wall on all four sides around both the platforms was erected with the bricks leaving approximately a 0.075 m space to a height of 0.675 m. River bed sand was used to fill the gap in one and the other was filled with rice husk ash. The complete schematic diagram of the evaporative cooling chamber is presented in **Fig. 1**. Once the evaporative cooling chambers were saturated with water, the river bed sand and rice husk ash were kept moist with an optimum quantity of water through a drip system with plastic pipes and microtubes connected to an overhead water tank. Top covers of the evaporative cooling chambers were prepared by gunny cloth pads with plastic sheets on one side to protect the dripping of water inside the cooling chambers. Comparative performance testing of evaporative cooling chambers at no load condition was carried out both for summer and winter for round the year use. The data were collected throughout the day at an interval of one hour to study the temperature and relative humidity profile inside and outside of the evaporative cooling chambers. The performance of both evaporative cooling chambers was compared on the basis of cooling efficiency.

Table 1 Dimensions of the evaporative cooling chambers

Particulars	Length, m	Breadth, m	Height, m
Brick size	0.22	0.11	0.075
Outer wall	1.65	1.15	0.675
Inner wall	1.28	0.78	0.675

Performance Parameters of Evaporative Cooling Chamber

Temperature

The temperature was recorded using a digital thermometer attached to thermocouples located at the centre of the evaporative cooling chambers and ambient environment. Over the entire period of study, the readings were taken at one hour interval during daytime.

Relative Humidity

The relative humidity was monitored with digital thermo hygrometer located at the centre of the evaporative cooling chambers and in the ambient environment.

Cooling Efficiency (Ce)

$$\text{Cooling Efficiency} = [(T_a - T_s) / (T_a - T_w)] \times 100$$

Ta = dry bulb temperature of ambient air, ºC

Ts = dry bulb temperature of the cooled space air, ºC

Tw = wet bulb temperature of ambient air, ºC

Fig. 1 Structural details of evaporative cool chamber

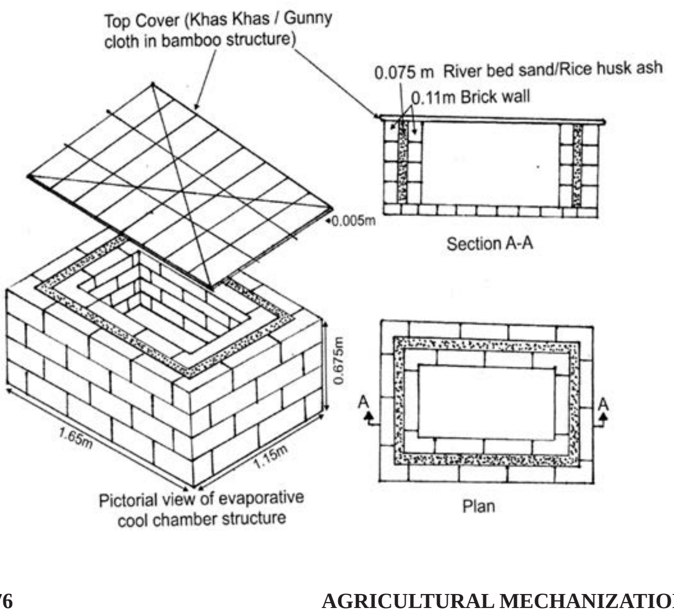
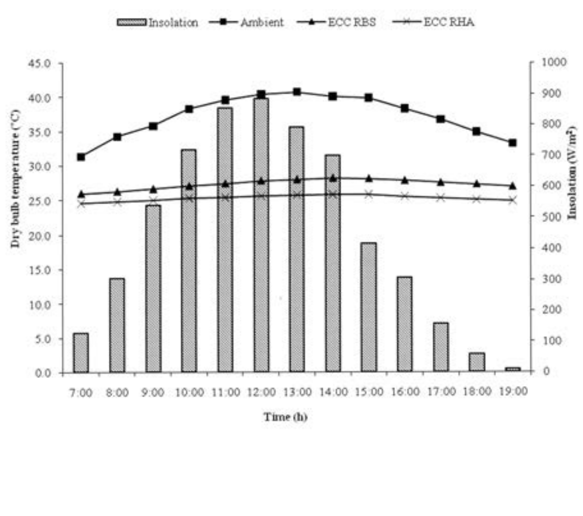


Fig. 2 Effect of day time on average dry bulb temperature (ºC) of ambient environment and evaporative cooling chambers during summer at no load



Results

Thermal Performance of Evaporative Cooling Chambers in Summer

The thermal performance of the evaporative cooling chambers was evaluated in summer season at no load. **Fig. 2** indicates that ambient average dry bulb air temperature varied from 31.4 °C to 40.7 °C, whereas the temperature inside ECC RBS varied from 25.9 °C to 28.2 °C and in ECC RHA varied from 24.6 °C to 25.8 °C, respectively. The solar insolation during the period varied from 10 W/m^2 to 884 W/m^2. The average difference in dry bulb temperature between ambient and ECC RBS was 9.9 °C and between ambient and ECC RHA was 11.9 °C.

The ambient relative humidity (**Fig. 3**) ranged from 24 % to 45 %, whereas in ECC RBS varied from 85 % to 92 % and for ECC RHA varied from 91 % to 97 %. The average difference in relative humidity between ambient and ECC RBS was 56 % and between ambient and ECC RHA was 61 %.

The cooling efficiency (**Fig. 4**) of evaporative cooling chambers in the summer season ranged from 57 % to 78 % and 73 % to 92 % in ECC RBS and ECC RHA, respectively. The average difference in cooling efficiency of ECC RHA was 16 % higher than ECC RBS.

Thermal Performance of the Evaporative Cooling Chambers in Winter

The thermal performance of the evaporative cooling chambers was evaluated in winter season also to know the seasonal variation. **Fig. 5** shows that the ambient dry bulb temperature varied from 18.4 °C to 22.8 °C whereas the temperature inside ECC RBS varied from 16.1 °C to 17.3 °C and in ECC RHA varied from 15.4 °C to 16.3 °C. The average solar insolation varied from 23 W/m^2 to 515 W/m^2. The average difference in dry bulb temperature between ambient and ECC RBS was 4.6 °C and between ambient and ECC RHA was 5.5 °C.

Ambient relative humidity (**Fig.**

Fig. 5 Effect of day time on average dry bulb temperature (°C) of ambient environment and evaporative cool chambers during winter at no load

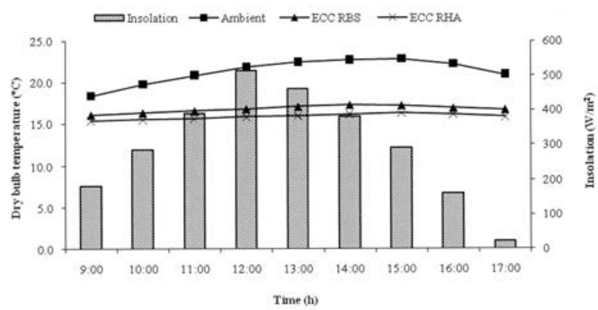


Fig. 3 Effect of day time on average relative humidity (%) of ambient environment and evaporative cooling chambers during summer at no load

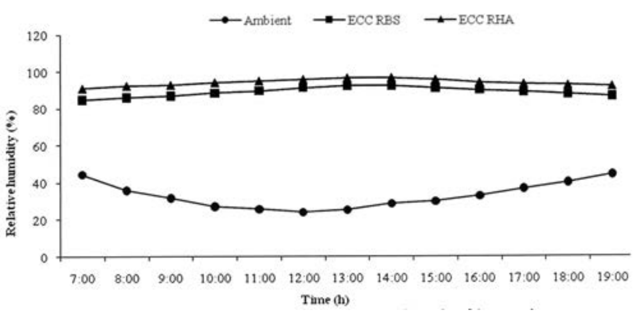


Fig. 6 Effect of day time on average relative humidity (%) of ambient environment and evaporative cooling chambers during winter at no load

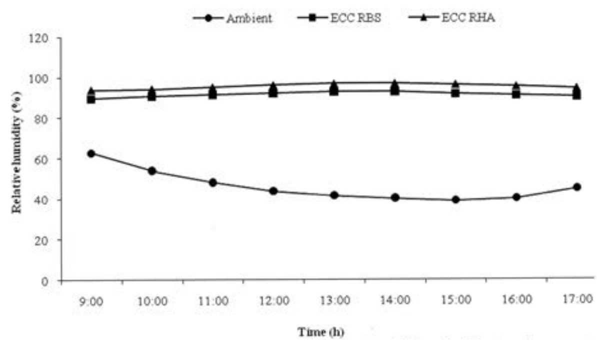


Fig. 4 Effect of day time on average cooling efficiency (%) of evaporative cool chambers during summer at no load

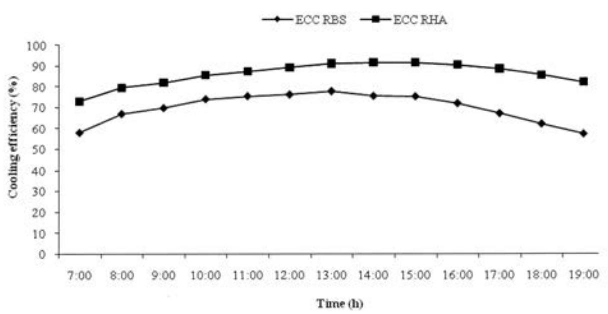
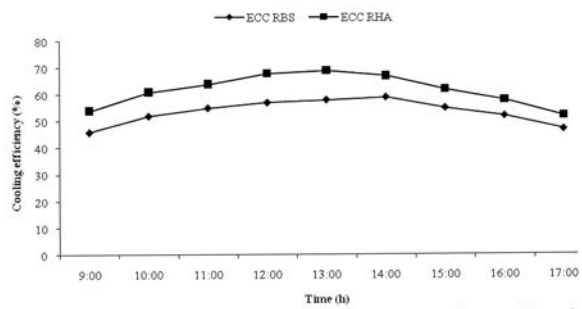


Fig. 7 Effect of day time on average cooling efficiency (%) of evaporative cooling chambers during winter at no load



6) in winter season varied from 39 % to 63 %, whereas in ECC RBS varied from 90 % to 93 % and ECC RHA varied from 94 % to 97 %, respectively. The average difference in relative humidity between ambient and ECC RBS was 45 % and between ambient and ECC RHA was 50 %.

Cooling efficiency (**Fig. 7**) in winter season varied from 46 % to 59 % and 52 % to 69 % in ECC RBS and ECC RHA, respectively. The average cooling efficiency of ECC RHA was 8 % higher than ECC RBS.

Discussion

The results of the study revealed that at no load condition the average difference in dry bulb temperature for summer and winter season between ambient and ECC RBS was 9.9 ºC and 4.6 ºC and between ambient and ECC RHA was 11.7 ºC and 5.5 ºC, respectively. The average difference in relative humidity for summer and winter season between ambient and ECC RBS was 56 % and 45 % and between ambient and ECC RHA was 61 % and 50 %, respectively. The average cooling efficiency of ECC RHA was 16 % and 8 % higher than ECC RBS for summer and winter, respectively. Seyoum (2002) reported that an evaporative cooler maintained temperature between 14.4 and 23.5 °C and relative humidity between 73 % and 92 %. Getinet *et al.* (2008) reported that in winter season the average difference in relative humidity and dry bulb temperature between ambient and inside the cooler were 54.8 % and 15.1 °C, respectively, and the evaporative cooler reduced dry bulb temperature by 5 ºC and raised the relative humidity by 18 % compared to single pad evaporative cooler. Similar findings were obtained by Nadre *et al.* (1999).

The maximum difference in dry bulb temperature between ambient and ECC RBS was 14.5 ºC and in ambient and ECC RHA was 16.4 ºC during the summer season when the average ambient temperature was 42.9°C. The maximum difference in relative humidity between ambient and ECC RBS was 71 % and in ambient and ECC RBS was 75 % when the average ambient relative humidity was 21 %. The results are in conformity with the findings of Dadhich *et al.* (2008) in a study on the evaporative cooling chamber with river bed sand.

Conclusion

The evaporative cooling chambers consistently recorded lower temperature and higher relative humidity than ambient. Evaporative cooling chambers were more effective in summer than winter and the evaporative cooling chamber with rice husk ash was more effective than the evaporative cooling chamber with river bed sand in almost all aspects and, hence, recommended for the safe storage of fresh fruits and vegetables for round the year.

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Design, Development and Performance Evaluation of Plantain Slicer

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Abstract

A plantain slicing mechanism with cutting blades fixed on a rotary disc for uniform slicing of the plantain was designed and developed. The slicer consisted of rotary disc fixed with stainless steel cutting blades to cut the plantain fruits into slices of uniform thickness and guiding the slices directly into the outlet or fryer. The plantain slicer was evaluated with three speeds of rotary disc at 264, 346 and 432 rpm and with three blade shapes: straight, convex and concave with plantain (var. Nendran). The highest percent standard slice of 95.8 % was observed for the convex blades followed by the straight blades (93.2 %) operated at 346 rpm. Lowest slicing time of 20 s and highest cleaning efficiency of 68.0 % was observed for the convex blades operated at 432 rpm. The slicer operated at 432 rpm with convex cutting blades gave the maximum capacity of 90 kg/h followed by the straight blade at the same speed. The cutting blade with convex shape was the best for efficient slicing in terms of slicing time, percent standard slices, cleaning efficiency and capacity.

Introduction

Banana (Musa sp.), known as common man's fruit due to its abundant year-round availability and nutritional value, is the largest produced and maximum consumed among the fruits cultivated in India. Bananas abound in hundreds of edible varieties that fall under two distinct species: the sweet banana (Musa sapienta, Musa nana) and the plantain banana (Musa paradisiacal). Sweet bananas vary in size and color. Plantain bananas are usually cooked and considered more like a vegetable due to their starchier qualities and they have a higher beta-carotene concentration than most sweet bananas. India ranks first among the banana cultivating countries in the world with an annual production of 23.2 million tons from an area of 0.64 million hectares and India's share of banana production is 29 % among the ten major banana producing countries of the world. (Indian horticulture data base, 2008).

Bananas are highly perishable and bulky which makes their transportation to distant and export markets costly. Most of the bananas produced in India are consumed fresh directly as raw ripe fruit. Hence, there is a need to process bananas into shelf stable, convenient and less bulky value added product. In India the processed banana product wildly manufactured on a commercial scale is chips. Processing of plantain into chips is one of the ways to reduce the post harvest losses of this crop. Bananas are often sliced length wise, baked or broiled and served or it may be thinly sliced and cooked (Hassanin, 2009). Traditional methods of processing bananas in most countries involve making the unripened bananas into chips, drying and storing as a famine food. (Muzanila and Mwakiposa, 2003). Bananas are made into chips by slicing the banana and frying by immersing in edible oil. Deep fried plantain chips are very popular snack foods in India and many countries. Chips production in India is totally under unorganized sector and an estimated quantity of more than 1.0 lakh tones of banana chips per annum is produced in Kerala and Tamil Nadu. (Anon, 2008)

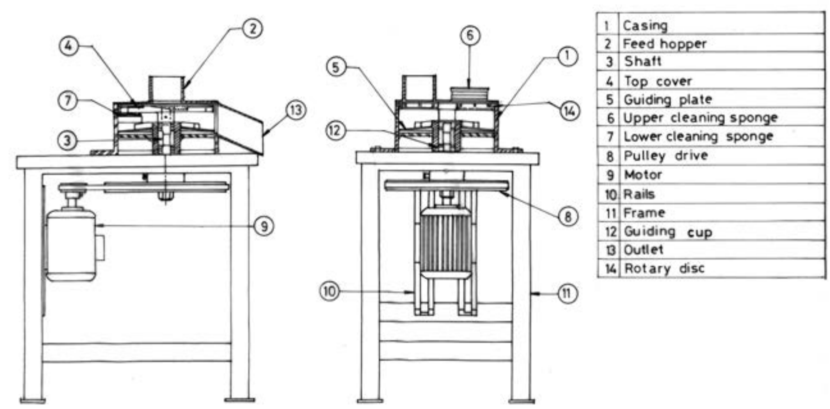
Kachru *et al.* (1995) determined the physical and mechanical properties of Dwarf Scavendish and Nendran varieties of green banana and the energy requirements to cut the fruits into slices. The maximum diameter of fruit without peel was 23.3 and 37.0 mm for dwarf Scavendish and Nendran. The maximum load and energy required to cut a cross sectional slice of the pulp was 22.4 N and 28.2 N and 686.8 and 724.4 J/m^2, respectively, for the Scavendish and Nendran. Onu and Okafor (2003) reported the effect of physical and chemical factors variations on the efficiency of mechanical slicing of Nigerian ginger.

At present the chips are made by hand peeling raw banana and slicing the pulp portion in a wooden platform type slicer with mild steel blades and then deep frying in the edible oil. The method is cumbersome, unhygienic and does not produce chips of uniform thickness and may cause injury to the operator while slicing. Hence there is a need to develop a machine which would enhance the capacity and slicing efficiency and reduce the drudgery in making the chips. A machine operated plantain slicer has been developed and its components, design details and performance are reported in this paper.

Materials and Methods

The developed plantain slicer consisted of feed hopper, rotary disc with blades, guiding plate, cleaning mechanism, outlet, power transmission units and the main frame to support these components. The mature plantain after hand peeling was fed through the feed hopper at a uniform rate. The plantain was sliced by a rotary disc fitted with stainless steel blades with the slices falling on the guiding plate moved to the outlet uniformly without sticking and collected or directly fed into the fryer. The front and side elevation plantain slicer is given in **Fig. 1**.

Fig. 1 Side and Front elevation of Plantain Slicer



Feed Hopper and Outlet

The feed hopper was designed to facilitate the continuous feeding of the plantain into the rotary disc with the feeding hood holding the plantain vertically. The external and internal diameters of the hopper were 70 and 60 mm, respectively, and the height of the hood was 50 mm. The number of hoods can be increased according to the capacity required. The outlet was designed along with the casing with an inclination of 220 with the horizontal.

Rotary Disc with Blades

The rotary disc was made up of aluminum and was fitted with two cutting blades made out of food grade stainless steel of three different shapes: straight, convex, and concave. The rotary disc was fitted to a central shaft by means of a slot on opposite sides inside the casing. The diameter of the rotary disc was 194 mm. The size of the stainless steel cutting blades were 86 × 47 mm for straight blade, 86 × 49 mm for concave blade and 86 × 57 mm for convex blades . Six screws were used to fit the cutting blades to the disc; three for each blade. A clear-

Fig. 3 Three shapes of cutting blades

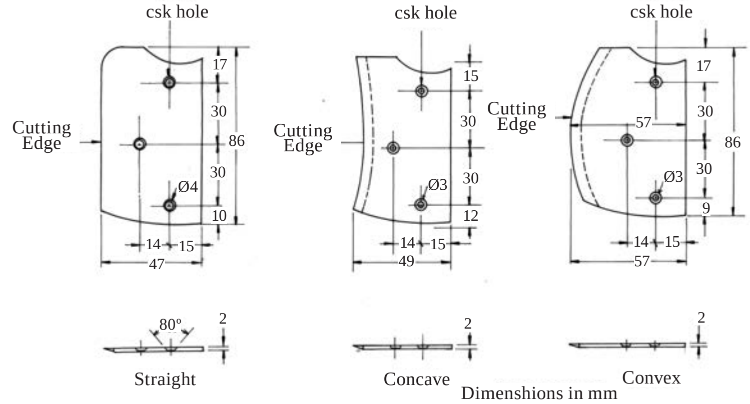
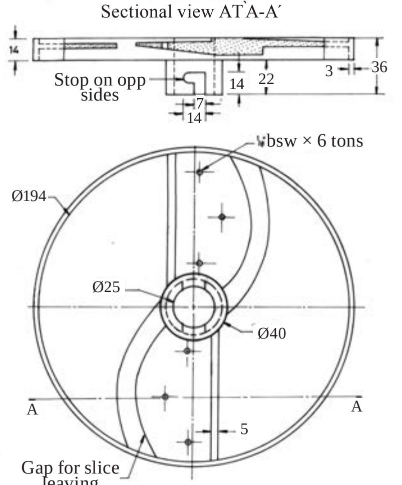


Fig. 2 Rotary Disc



ance was allowed for each blade along its cutting edge for the slices to pass through to the outlet via the guiding plate. These blades could be dismantled and fitted as and required. The rotary disc and the three shapes of cutting blades are shown in **Figs. 2** and **3**, respectively.

Guiding Plate

A guiding plate was provided below the rotary disc and was fitted to the central shaft by means of a groove similar to the rotary disc. The guiding plate rotated at the same speed of the rotary disc. The main purpose of this guiding plate was to distribute the slices individually into the fryer so that clumping of slices could be avoided. The diameter of the guiding plate was 200 mm. The guiding plate was welded with two angular curves with a central circular round for uniform distribution of the slices. The guiding plate rotated at the same speed of the shaft and rotary disc. The guiding plate was food grade stainless steel and it was removable and could be cleaned easily.

Main Frame

The main frame was fabricated using 38 × 6 mm, mild steel L-angle and used to support the components of the slicer motor pulleys and switches. The dimensions of the frame were 500 × 356 × 508 mm. The upper surface of the frame was made of mild steel and the dimensions of the flat surface was 514 × 387 × 25 mm.

Cleaning Mechanism

A sponge which is mounted on a spring loaded fixture is placed at the bottom on any one side of the rotary disc. The sponge arrangement was provided to keep the cutting blades clean. A sponge was mounted at the top of the casing on the opposite side of the feeding hood that could be engaged as required. The cut out given for fixing the sponge was 79 × 19 mm. The sponge provided at both the top and bottom sides could be replaced as required. The dimension of the sponge placed at the top was 76 × 16 × 32 mm and at the bottom was 50 × 16 × 21 mm.

Power Transmission

The power was transmitted from the motor to the shaft by means of pulleys. The diameter of the shaft (driven) pulley was constant and the diameter of the driving pulley was changed according to the speed required. The speed of the driven pulley and the diameter of the driving pulley could be calculated from the following formula

$N_1 D_1 = N_2 D_2$

$N_2 = (N_1 D_1) / D_2$

where

N_1 is the speed of the motor, rpm

N_2 is the speed of the driven shaft, rpm

D_1 is the diameter of the pulley mounted on motor shaft, m

D_2 is the diameter of the pulley mounted on driven shaft, m

Therefore, the speed of the driven shaft $(N_2) = 1440 \times (2.54 \times 3) / 25.4 = 432$ rpm

The shaft was made of mild steel and was subjected to combined bending and twisting moments. It was subjected to fluctuating loads since the plantain slices were fed into the slicer at regular time intervals. Hence, the shock and fatigue factors were taken into account while calculating the twisting and bending moment. The diameter of the shaft was calculated using the following formula:

Torque transmitted by the shaft,

$T = (P \times 60) / 2\pi N$ (Khurmi, 1990)

where,

P, power transmitted by the shaft, W

N, speed of the shaft, rpm

Maximum bending moment for a shaft loaded on both the ends was given by

$M = W \times L$

where,

W, was the load acting on the shaft, N

L, was the length of the shaft, mm

The equivalent twisting moment,

$T_e = \sqrt{(K_m \times M)^2 + (K_t \times T)^2}$

where,

K_m = combined shock and fatigue factor for bending, 1.5

K_t = combined shock and fatigue factor for torsion, 1.5

But equivalent twisting moment,

$T_e = \pi / 16 \times \tau \times d^3$

where,

τ, maximum allowable shear stress, which was about 42 N/mm^2 for shafts with allowance for keyways

d, was the diameter of the shaft, mm

The diameter of the shaft could also be calculated by using equivalent bending moment. Using the above formulas, the diameter of the shaft was about 19 mm and the length of the shaft was 195 mm.

Performance and Evaluation of the Slicer

Plantain (var. Nendran) of proper maturity was procured from the local market. The matured plantain fingers were peeled by stainless steel knives. The peeled samples (0.5 kg/batch) were fed into the slicer through the feeding hood, mounted in such a way that it opened directly to the centre of the blades attached to the rotary disc. The disc was operated at different speeds till the plantains were sliced. A gap in between the blades and the disc plate allowed the cut slices to fall by gravity into the discharge port. Slicing experiments were conducted by varying the disc speeds; 264, 346 and 432 rpm. The effect of shape of cutting blade and speed on the various parameters like slicing time, percentage yield of standard slices, yield of non standard slices, percentage solid loss, capacity of the slicer and the cleaning efficiency were determined.

Slicing Time

The slicing time for plantains was

determined by taking the time required for the plantain slicer to slice 0.5 kg of plantain.

Percentage Yield (Standard Slice and Non-Standard Slice)

The quantity of plantain slices that fell within the thickness range of 1.75 ± 0.25 mm and the slices that were uniform and devoid of damage were measured and regarded as standard, while the slices that were damaged and outside the range were regarded as non-standard.

% Yield (Standard slice), % = (Mass of standard slices / Initial mass of plantain) × 100

% Yield (Non Standard slice), % = [(Mass of non − standard slices) / Initial mass of plantain)] × 100

Percentage Solid Loss

Solid loss was calculated by subtracting from the initial mass of plantains, the sum of mass of standard and non-standard slices.

Solid loss, % = Initial mass − (Mass of standard slices + Mass of non standard slices) / Initial mass

Cleaning Efficiency

A known weight of plantain was taken and sliced uniformly. Before slicing, the initial weight of the blades was measured using an accurate balance that weighed to three decimal places. After slicing a known quantity of the plantains, the blades were removed and the weight of the starch that had settled on the blade was weighed. After subjecting it to cleaning operation the blades were again removed and weighed to determine the efficiency of cleaning using the brushes.

Weight of the starch present in the blades = $w_2 - w_1$

Cleaning efficiency, % = $(w_3 - w_2 / w_2 - w_1) \times 100$

where,

w_1 - initial weight of the blades, g

w_2 - weight of the blades after slicing/before cleaning, g

w_3 - weight of the blades after cleaning, g

Capacity

The throughput of the machine was determined by calculating the time of operation and weight of the plantains sliced.

Capacity (kg/h) = [Quantity (wt) of sliced plantains (kg) / Operating time (s)] × 3600

Table 1 Effect of blade design and speed on the performance of plantain slicer

		Speed, rpm		
Parameters	Blade design	264 (S_1)	346 (S_2)	432 (S_3)
Slicing time, s	Straight (B_1)	56	37	22
	Convex (B_2)	55	34	20
	Concave (B_3)	65	45	32
Percent standard slices	Straight (B_1)	90.8 ± 1.18	93.24 ± 2.87	82.55 ± 1.74
	Convex (B_2)	87.88 ± 1.01	95.87 ± 2.23	94.11 ± 3.22
	Concave (B_3)	42.29 ± 2.63	42.92 ± 2.57	36.38 ± 2.87
Percent non standard slices	Straight (B_1)	3.06 ± 0.81	3.51 ± 1.05	7.35 ± 2.51
	Convex (B_2)	5.31 ± 0.74	3.07 ± 2.25	3.59 ± 2.87
	Concave (B_3)	27.74 ± 8.07	32.57 ± 2.52	34.27 ± 4.93
Percent solid loss	Straight (B_1)	6.13 ± 1.49	3.24 ± 3.44	10.09 ± 1.52
	Convex (B_2)	6.80 ± 1.70	1.05 ± 0.07	2.29 ± 0.35
	Concave (B_3)	32.64 ± 4.96	24.50 ± 2.13	29.35 ± 2.13
Cleaning efficiency, %	Straight (B_1)	48.00	52.50	54.32
	Convex (B_2)	54.25	61.04	68.01
	Concave (B_3)	35.26	32.24	25.62
Capacity, kg/hr	Straight (B_1)	32.14	48.64	81.81
	Convex (B_2)	32.72	52.94	90.00
	Concave (B_3)	27.69	40.00	56.25

Results and Discussion

The developed plantain slicer with three different shapes of cutting blades was evaluated at speeds of 264, 346 and 432 rpm and the performance of the slicer with reference to different parameters are presented in **Table 1**.

Slicing Time

Slicing time decreased as the speed increased for both straight and convex blades and the decrease in slicing time was not appreciable when concave shaped blades were used, which might have been due to the irregular slicing and accumulation of broken slices in the clearance below the blades. This might have clogged and prevented the blade from slicing the pulp.

Percentage Yield of Slices (Standard and Non-Standard)

The percentage of standard slices was calculated from the representative samples collected after slicing. The yield of standard slices was 93.24 percent at 346 rpm which was the highest value for straight blade whereas the yield was 95.87 percent for convex blade and 42.92 percent for concave blade at the same speed.

The amount of non-standard slices often referred to as broken slices was 3.06 percent for 264 rpm which was the lowest value for straight blade whereas it was 3.07 percent for convex blade at 346 rpm and 27.73 percent for concave blade at 264 rpm.

Percentage Solid Loss

Solid loss of 1.05 percent at 346 rpm was the lowest among the nine combinations whereas it was 24.50 percent and 3.24 percent at the same speed for concave and straight blades, respectively.

Capacity

The highest capacity of 90 kg/h was for a slicer speed of 432 rpm with convex blade followed by 81.81

kg/h for a slicer speed of 432 rpm with a straight blade.

Capacity increased as the speed increased and the performance of straight and convex blades were good when compared to concave blades.

Cleaning Efficiency

The highest cleaning efficiency of 68 percent was at the slicer speed of 432 rpm using the convex blade whereas it was 61 percent for the same blade at 346 rpm followed by 54 percent for straight blades at 432 rpm.

It can be concluded that the convex blade was yielded good results with higher percentage of standard slices, efficient cleaning and minimal solid loss.

Conclusions

A plantain slicer with rotary disc and cutting blades of three different blade designs viz. straight, convex and concave was designed .The slicer was evaluated for its performance with the plantain (var. Nendran) by varying the speeds of the drive shaft as 264, 346 and 432 rpm. Convex blades at 346 rpm gave the best performance in terms of percentage of standard slices (95.8 %) cleaning efficiency (61.0 %) and the capacity of the slicer with the convex blade at 432 rpm was 90 kg/h.

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Economics of Basin-lister cum Seeder for In-situ Moisture Conservation in Drylands of Indian Cotton Fields

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Abstract

Basin-lister cum seeder is an in-situ moisture conservation machine used to create a multitude of small basins on the surface of the dryland by which even a relatively small amount of water can be stored in the soil prior to sowing of crops. The present paper analyzes feasibility and economical viability of the equipment in Indian drylands. The cost economics was arrived as per the "BIS standard IS 9164 (1979) on Guide for estimating cost of farm machinery operation" and "RNAM test codes and procedures for farm machinery". The material, labour, and fabrication costs were compared with the cost of operation by the conventional method. The cost of the machine was Rs. 30,000 and the cost of operation was Rs.2,602 per ha. The savings in cost, time, and energy compared to conventional method were 54.84, 99.11 and 17.73 percent, respectively. The break even point and the pay back period of the basin-lister cum seeder attachment were 93.68 ha/annum and 2.75 years, respectively.

Introduction

Only 143 m ha in India are under cultivation out of a total geographical area of 329 m ha. Even after realizing the complete irrigation potential of the country, 50 percent of the cultivated area will continue to depend on the rainfall. In the past three decades, the rate of growth of food production has more or less kept pace with the population growth, mainly due to the productivity gains from irrigated areas following the green revolution. Currently, irrigated areas produce an average of 2 tonnes of food grains per hectare. The average productivity in rainfed areas is only 0.7 to 0.8 t/ha according to Singh and Venkateswarlu (1999). About 70 percent of the cultivated land is rainfed, which depends on natural precipitation for crop production (Mahipal *et al*., 1996) and rainfed agriculture accounts for 45 percent of cereals and 75 percent each of pulses and oil seeds (Hazra, 1998).

In dryland farming it is important to have even a relatively small amount of water stored in soil prior to sowing of crops and this can be achieved effectively by creating a multitude of small basins. Moreover the land has to be ploughed once before operating the sowing unit. Hence, a basin-lister cum seeder as an attachment to a tractor drawn cultivator was developed to perform ploughing, basin formation and sowing simultaneously. The unit was developed as a rear mounted attachment to a four-wheel tractor of the 35-45 hp range and consisted of common cultivator components, a three bottom basin-lister and a cup feed type seeder.

The main objectives of this paper were to analyze cost involved in fabrication and labour and to determine the feasibility and economical viability of a basin-lister cum seeder on Indian farms.

Materials and Methods

Concept of Basin-Lister Cum Seeder

Sowing of the major crops raised under rainfed conditions like groundnut, cotton, sorghum, pearl millet, maize and pulses are seasonal and have to be completed before moisture is depleted. In the existing methods of land preparation, the moisture retained by the soil is less since more water is wasted in the form of runoff. Hence, the available time for sowing is minimized due to immediate depletion of moisture. Moreover before operating the sowing unit the land has to be ploughed once. Development of separate units for each operation will be costly. Hence, if a basin-lister cum seeder as an attachment to tractor drawn cultivator is developed, it can perform ploughing, basin formation, and sowing simultaneously (Kumar, *et al*., 1990).

Description of the Unit

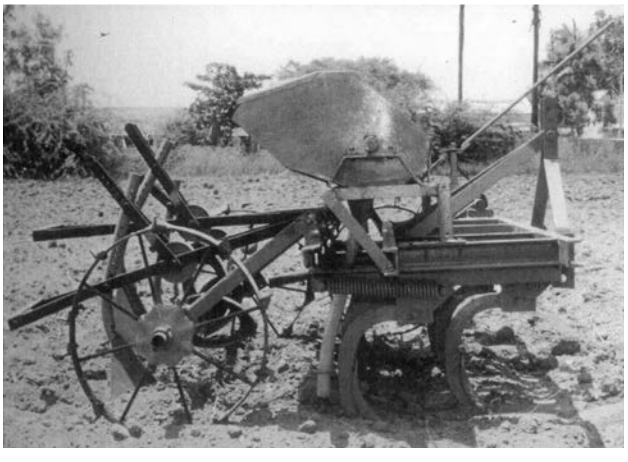
The unit was designed and developed to suit various soil conditions. The developed unit performed several operations simultaneously; viz., ploughing once, forming basins and sowing seeds in the centre of two adjacent basins at the desired spacing and depth in a single pass.

Nine tynes were mounted on the cultivator mainframe with five mounted in the front row at 450 mm intervals and the remaining four mounted in the rear row at 450 mm intervals. This permitted the four seed tubes at the rear side to sow seeds in four rows at 450 mm row spacing. The seed hopper was mounted on the main frame of cultivator. The ground wheel assembly of the seeder was mounted at the left side of the cultivator so that the basins formed were not disturbed. The lister bottoms were fixed with shanks and the shanks were fixed with follower arms. The three follower arms were hinged independently to the cultivator frame, at 450 mm intervals. The cams with dimensions identified in the design were mounted on the camshaft at 450 mm linear intervals as well as 120º radial intervals. Two 764 mm diameter ground wheels were provided on a camshaft, and 15 lugs of 60 × 40 mm size were riveted onto their rim. One wheel was made a drive wheel by fixing rigidly to the camshaft.

Thus, the basin-lister unit consisted of four main assemblies. First, there were three sets of listers with shank and follower arms with each set hinged separately to the cultivator frame at 450 mm intervals such that each set oscillated independently. The fourth assembly consisted of two wheels with a shaft where cams were mounted at 450 mm intervals such that they were directly below the cam follower when assembled. The set up was also hinged to the cultivator frame independently.

During the forward movement of the unit, the cultivator tynes till the land, the lister bottom forms the basin and the seed planting mechanism meters seed and places them in the desired location. The plant to plant spacing could be varied by altering the speed ratio between the ground wheel and the seed metering shaft by changing the sprockets in the power transmission system of the seeder. This could also be achieved by changing the number of cups in the seed metering disc. The desired depth of placement of seed could be accomplished by moving the seed placement tube vertically up or down. The unit is shown in **Fig. 1**.

Fig. 1 Basin-lister cum seeder



Cost Analysis

The annual costs of operating a machine can be divided into two categories; viz, fixed cost and variable cost or running cost. The fixed costs are constant per annum and will, thus, decrease per hectare as the annual use of the machine increases. The running costs are constant per hectare and, thus, the annual cost increases in proportion to the annual use. The fixed costs consist of depreciation, interest on capital, insurance, housing and taxes where applicable. The variable costs comprise repairs and labour, together with fuel and tractor use where applicable. Based on the materials used and labour requirement for the fabrication, the material cost and fabrication cost of the unit were calculated.

The cost of operation per ha was worked out using the procedure recommended by RNAM test codes (Anon, 1995). This cost was compared with the conventional method (Nelson *et al*., 2000). The savings in cost, time and energy by using the machine as compared to the conventional method was compared. The break even point and pay back period also were computed for the machine (Ahmed, 1985).

Results and Discussion

Cost Economics

The cost, time, and energy requirement of the basin-lister cum seeder and conventional method were calculated and compared. The cost of the basin-lister cum seeder was calculated based on materials and labour requirement. The cost of operation of the basin-lister cum seeder was calculated by using the procedure recommended by BIS standard IS 9164 (1979) on "Guide for estimating cost of farm machinery operation" and "RNAM test codes and procedures for farm machinery".

Cost of operation of basin-lister cum seeder attachment, Rs./h = 24.21

Cost of operation by basin-lister cum seeder including tractor charge, Rs./h = 314

The field operations carried out by basin-lister cum seeder and conventional method in the cotton field in the July season are furnished in **Table 3**.

Cost Appraisal

a) Basin-lister cum seeder

i. Disk ploughing: Width of operation was 0.75 m and speed of operation 3 km/h and the field capacity was 0.18 ha/h (Considering field efficiency as 80 % as given by Hunt, 1977). So, time requirement was 5.56 h/ha.

Cost of operation, Rs./ha = 5.56 × 290 = 1,612

ii. Cultivator: Width of operation was1.8 m and speed of operation 5.6 km/h (Kepner, 1987) and the field capacity was 0.8266 ha/h (Considering field efficiency as 82 % from Hunt, 1977). So, time requirement for completing a unit area was 1.21 h/ha.

Cost of operation, Rs/ha = 1.21 × 290 = 350

iii. Mechanized basin listing cum seeding:

Table 1 Cost appraisal for tractor

Particulars	Cost, Rs.	
	Annual	Per hour*
I. Fixed cost		
Depreciation	(300,000 − 30,000) / 15 = 22,000	22.00
Interest @ 10 % of average price	[(300,000 + 30,000) / 2] × 0.10 = 16,500	16.50
Housing (1.5 % of purchase price)	300,000 × 0.015 = 4,500	4.50
Taxes (1 % of purchase price)	300,000 × 0.01 = 3,000	3.00
Insurance (1 % of average price)	[(300,000 + 30,000) / 2] × 0.01 = 1,650	1.65
II. Variable cost		
Repair and maintenance	10% of purchase price	30.00
Labour (Driver) @ Rs.250/day		31.25
Fuel @ Rs. 40/litre (4.11 l/h)		164.40
Lubrication, 10% of fuel cost		16.44
	Cost of operation of tractor, Rs./h	290.00

*Calculated by assuming annual working hours as 1,000 hour (Hunt, 1977)

Table 2 Cost appraisal for basin-lister

Particulars	Cost, Rs.	
	Annual	Per hour*
I. Fixed cost		
Depreciation	(30,000 − 3,000) / 15 = 1,800	2.25
Interest @ 10 % of average price	[(30,000 + 3,000) / 2] × 0.10 = 1,650	2.06
Housing (1.5 % of purchase price)	30,000 × 0.015 = 450.00	0.56
Taxes (1 % of purchase price)	30,000 × 0.01= 300.00	0.38
Insurance (1 % of average price)	[(30,000 + 3,000) / 2] × 0.01 = 165	0.21
Total fixed cost	4,365	5.46
II. Variable cost		
Repair and maintenance	10 % of purchase price	3.75
Labour (1 Woman) @ Rs.120/day		15.00
Total variable cost		18.75

*Calculated by assuming annual working hours as 800 hour (Hunt, 1977)

Table 3 Field operations carried out cotton field

Basin-lister cum seeder	Conventional method
Ploughing once with tractor drawn disk plough	Ploughing once with tractor drawn disk plough
Ploughing once with tractor drawn cultivator	Ploughing twice with tractor drawn cultivator
Operating once basin-lister cum seeder (ploughing, basin listing and sowing)	Formation of basins manually
	Planting manually

Table 4 Cost of unit operations

Method	Cost of unit operation, Rs./ha			
	Disc ploughing	Cultivation	Basin formation and sowing	Total cost
Basin-lister cum seeder method	1,612	350	640	2,602
Conventional method	1,612	700	3,450	5,762

Table 5 Appraisal of cost, time, and energy

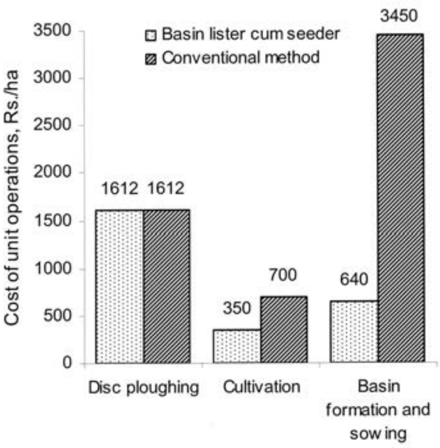
Method	Cost, Rs./ha	Time, h/ha	Energy, MJ/ha	Percent saving in		
				Cost	Time	Energy
Basin-lister cum seeder method	2,602	8.81	1,522.37	54.84	99.11	17.73
Conventional method	5,762	237.98	1,850.44	--	--	--

Field capacity of the unit, ha/h = 0.49
Time required, h/ha = 1/0.49 = 2.04
Cost of operation, Rs/ha = 2.04 × 314 = 640
Total cost of operation in basin-lister cum seeder method, Rs./ha = 2,602

b) Conventional method

i. Disk ploughing:
Cost of operation, Rs/ha = 1,612
ii. Cultivator twice:
Cost of operation for operating twice, Rs/ha = 700
iii.Basin formation:
Man-hours required/ha =150;
Cost of operation, Rs./ha = (150 / 8) × 120 = 2,250
iv. Planting:
Women hours required / ha = 80
Cost of operation, Rs/ha = (80 × 120) / 8 = 1,200

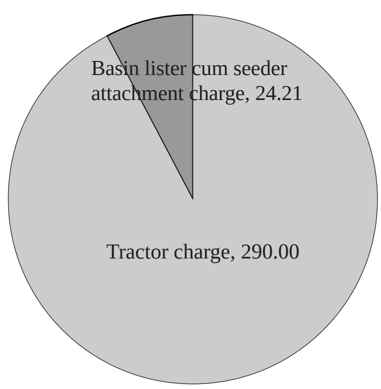
Fig. 2 Comparison on cost of unit operations



Total cost of operation in conventional method, Rs/ha = 5,762
Cost of operation with basin-lister cum seeder Rs/ha = 2,602
Saving in cost, Rs/ha = 3,160
Saving in cost compared to conventional method, percent = 54.84

Table 4 reveals that the total cost of operation was halved with the basin-lister cum seeder compared to the conventional method since there was drastic reduction in cost of cultivation, basin formation and sowing operations were in the mechanized mode although there was no significant difference in ploughing operation. For basin formation and sowing operation only, the equipment registered 81.45 percent of saving in cost compared to the conventional method. This was a great economic achievement with the equipment in addition to reduction in human drudgery. This is pictorially shown in **Fig. 2**.

Fig. 3 Cost of operation of basin-lister cum seeder



Time Appraisal

a) Basin-lister cum seeder

Time required, h/ha = 2.04

b) Conventional method

i. Basin listing:
Time required, h/ha = 150
ii. Planting:
Time required, h/ha = 80
Total time required, h/ha = 150.00 + 80.00 = 230
Saving in time = 227.96

Saving in time as compared to conventional method, percent = 99.11

Energy Appraisal

a) Basin-lister cum seeder

i. Disk ploughing:
Time required = 5.56 h/ha; Fuel consumption = 5 l/h
Therefore, Energy required = 1,006.92 MJ/ha
ii. Cultivator:
Time required = 1.21 h/ha; Fuel consumption = 4.832 l/h
Therefore, Energy required = 211.77 MJ/ha
iii. Basin-lister cum seeder:
Time required = 2.04 h/ha; Fuel consumption = 4.11 l/h
Therefore, Energy required = 303.68 MJ/ha
Total energy requirement with basin-lister cum seeder = 1522.37 MJ/ha

b) Conventional method

i. Disk ploughing:

Energy requirement, MJ/ha = 1,006.92

ii. Cultivator (twice):

Energy requirement, MJ/ha = 211.77 × 2 = 423.54

iii. Basin formation:

Time required = 150 man.h/ha

Equivalent energy for 1 man power = 1.9625 MJ/ha (Anon, 1996)

Energy requirement = 1.9625 × 150 = 294.38 MJ/ha

iv. Planting:

Time required = 80 h/ha;

Equivalent energy for 1 woman power = 1.57 MJ/ha (Anon., 1996)

Energy requirement = 1.57 × 80 = 125.60 MJ/ha

Total energy required in conventional method = 1,850.44 MJ/ha

Saving in energy = 328.07 MJ/ha

Saving in energy with basin-lister cum seeder method = 17.73 percent

Break even point

BEP, ha/annum = Annual fixed cost / (Custom fee Rs./h − Operating cost, Rs./h) × Effective field capacity, ha/h

Custom fee, Rs./h = (Cost of operation/h + 25 % over head charges) + 25% profit over new cost = (24.21 + 24.21 × 0.25) × 1.25 = 37.83

Operating cost, Rs./h = 15.00; BEP, ha/annum = 93.68

Annual utility, kg = Effective field capacity, ha/h × Annual utility period, h = 0.49 × 800 = 392

Therefore, the BEP of basin-lister cum seeder attachment is achieved at 23.89 (i.e. 93.68 × 100/392) percent of the annual utility rate of 800 hours of the basin-lister cum seeder.

Pay Back Period

Pay back period, year = Initial cost of machine / Average net annual benefit

Average net annual benefit, Rs. = (Custom fee, Rs./h − Total cost of operation, Rs./h) × Annual utility rate, h = (37.83 − 24.21) × 800 = 10,896

Pay back period, year = 30,000 / 10,896 = 2.75

The appraisal of cost, time and energy for basin-lister cum seeder and conventional method are furnished in **Table 5**. The comparison on cost of operation of basin-lister cum seeder and conventional method are shown in **Fig. 3**.

Conclusion

A savings of 54.84 percent in cost of operation was achieved by adopting the basin-lister cum seeder over the conventional method in addition to the reduction in drudgery of operation in manual basin formation and planting behind the country plough. Since the time requirement with the equipment to complete the task was much less (2.04 h/ha) compared to that of the conventional method (230 h/ha), there was 99.11 percent saving of time with the mechanized operation. The total energy requirement for using the unit was 1,522.37 MJ/ha whereas that of the conventional method was 1,850.44 MJ/ha, which denotes the machine registered 17.73 percent energy saving. The break even point (93.68 kg/annum) and pay back period (2.75 year) of equipment were satisfactory. On summarizing, by considering the cost of picking, break even point, pay back period, cost saving, time saving, and energy saving, this in-situ moisture conservation equipment was promising. The critical analysis on economic viability of adopting the basin-lister cum seeder in Indian drylands showed a definitive and positive pathway to store moisture in the root zone. It was concluded that there was a very great scope for the basin-lister cum seeder in Indian drylands as the machine was not only technically feasible but also economically viable.

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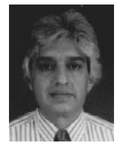
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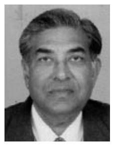
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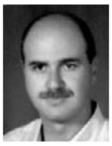
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