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EDITORIAL

The oil price is going up throughout the world, having already exceeded 70 dollar per gallon. The diesel oil for my car that cost 70 yen per litter last year has risen to as high as 120 yen per litter.

People in advanced nations, especially in The U.S., largely depend on cars in their social life. They need cars to go shopping or to do anything. The life without cars could be hardly imagined there. The rise of oil price also hit greenhouse farmers in Japan. They have to use expensive heating oil for growing crops in cold season.

Man can exist on the earth only through co-existence with other life system. Energy, fresh water, soil, forest and microorganism in soil are essential resources. Not only energy resource but also fresh water is in short supply on the whole world. As one of the solutions to global warming, renewable energy is receiving much attention these days. Biomass project called “Biomass Japan” started in Japan.

Agricultural mechanization we promote is one form of energy input to agriculture. Increasing agricultural productivity on a global scale is essentially needed to support growing population. In particular improving inefficient farming operation in developing countries is the most important issue in the 21st century. Agricultural machines can increase land productivity as well as labor productivity. Raising land productivity by mechanization must be of primary importance in this century. There is still a funny misunderstanding in some quarters that agricultural machines waste energy because they use energy. The reality is that agricultural mechanization raises energy efficiency in agriculture as a whole and is essential to efficient production of biomass. We must promote mechanization of agriculture especially in developing countries for our survival on this narrowing earth.

We, agricultural engineering profession, have a large task to attend to in this century. In the stupid world trend that the most important keyword like agriculture or agricultural machines is likely to disappear, we should make sustained efforts in promoting agricultural mechanization.

AMA will continue to support our large task.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
August, 2006

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Optimisation of Machine Prameters of Pneumatic Knapsack Cotton Picker

by

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Abstract

Harvesting is one of the major labour intensive operations in cotton cultivation. Since cotton varieties used in our country require picking at several stages, the use of mechanical pickers is not feasible. Therefore, a pneumatic backpack picker was considered. The dimensions of the machine components viz., pick up pipe diameter, filter type, filter height, capacity of collection drum and speed of aspirator were optimised through statistical analysis. The combination of a 25 mm diameter pick up pipe, a nylon mesh filter 225 mm high, a 25 litre collection drum and a 5,500 rpm aspirator speed developed maximum pressure. It was found that the field capacity for the first picking (4.93 kg/h) was less than that for the third picking (5.07 kg/h). The field capacity was highest for the P4 variety (5.20 ± 0.03 kg/h) and lowest for the Sumangala variety (4.85 ± 0.06 kg/h). The picking efficiency was less (96.35 %) in first picking and more (97.48 %) in third picking. The picking efficiency was highest for the MCU12 variety (97.83 ± 0.15%) and lowest for the Anjali variety (96.45 ± 0.20 %). The trash content in the machine picked cotton was a maximum of 13.97 % in the third picking. The energy consumption for the picker was 2,389.70 ± 112.96 kcal/day. The maximum sound pressure created by the picker was 100.45 ± 2.25 db. The saving in cost, time and energy in machine picking compared to conventional picking was 9.00, 75.00 and 68.23 % respectively.

Introduction

Cotton is grown on 32.8 million hectares in 80 countries with an average annual production of 18.6 million tonnes during 2000-2001 (Anon, 2001). The share of cotton in world textile production is 45 % and its production, processing and marketing sustains more than 250 million persons.

The growth of cotton and cotton textiles is intimately related at all periods of the culture and history of India. The British Empire, for over a century, from 1840 AD, made a large fortune on Indian cotton because of the availability of cheap raw material for its world encompassing textile industry. Among the fibre crops, cotton provides about 80 % of the raw material for the manufacture of textiles in the country. Today cotton is the number one agricultural commodity, sustaining Indian economy (38 %) with export earnings worth Rs.358.72 billion (Alam, 2000). India is currently first in area, second in yarn production and third in raw cotton production in the world. In India, the cotton crop is cultivated on 8.122 million ha with a production of 13.75 million bales at an average of 295 kg/ha (Anon, 2001).

Mechanical cotton harvesters are not considered suitable for Indian conditions, considering the cultural and agronomic practices and the staggered blooming characteristics of Indian cotton plant. Indian cotton varieties must be picked at several stages and which lead to selective picking methods. A possible solution is the pneumatic system of picking which has been addressed in this investigation.

Review of Literarure

Bennett (1938) reported that mechanical cotton pickers gathered from 4.7. to 7.1 % of foreign matter as compared with 1.8 to 6.6 % by hand picking. There was a striking difference in appearance between cotton picked by spindle picker and those which have been carefully hand picked. At the gins, it was possible to remove 53 % of total of 5.9 % of foreign matter (mostly leaf trash) from the mechanically picked as compared with 66 % from a total of 4.2 % of foreign matter (mostly burs) in the hand picked cotton.

Krish et al (1980) studied the effect of number of pickings on the quality and other character of Giza 67 cotton varieties and concluded that the seed cotton yield were increased with 2 or 3 pickings. Lint percentage was not affected by the number of pickings. Idiyatullin et al (1984) developed a cotton harvester fitted with electrical drivers for its pneumatic conveyor and harvesting system. Work quality similar to that of the control was achieved, while efficiency was improved by extended working time, improved layout, reduced component weight and more complete power utilization. Kumar et al (1988) analyzed the effects of the boll position (upper, middle, or lower portion of the plant canopy) and picking intervals on the quality of cotton and reported that the first two pickings and bolls borne on the upper canopy were the major factors affecting seed cotton yields. The boll position had significant effect on seed quality parameters.

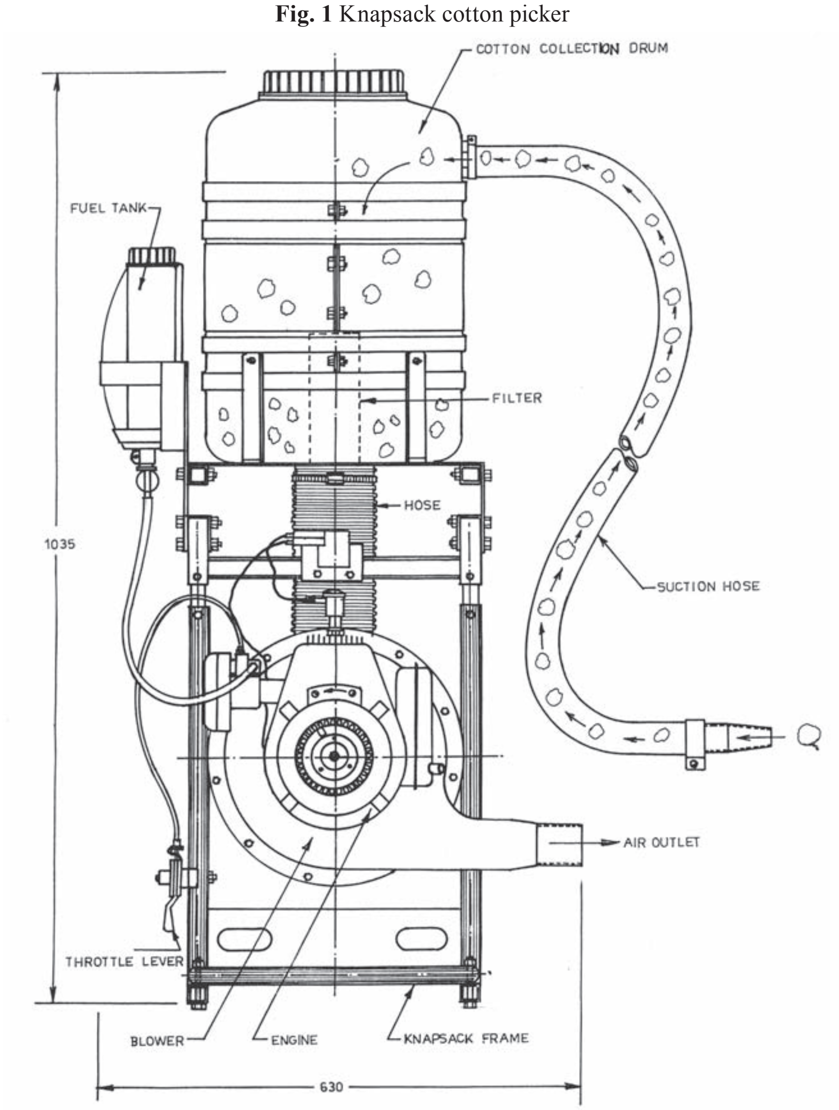
Nelson et al (2000) studied the cost of six harvesting methods for cotton; four, six and eight-row strippers with and without bur extractors. Results indicated that a typical cotton producer with 235 ha and a lint yield of 586 kg would minimize the cost of harvesting by owning a four-row stripper with or without a bur extractor. The stripper system without a bur extractor showed a minimum harvesting cost with the four-row stripper up to 567 ha and with the six-row stripper for farms larger than 607 ha. The eight-row stripper without a bur extractor was not found to minimize harvesting costs for any of the farm sizes examined. For stripper alternatives with bur extractors, the harvesting cost was minimized by the four-row stripper up to 324 ha, the six-row stripper for farms 364-891 ha and the eight-row stripper for farms larger than 931 ha. Kumar and Parvathi (2001) reported that the energy expenditure for cotton harvesting was 1,300 kcal/day.

Materials and Methods

Selection of Cotton Varieties

Twenty varieties of cotton crop were selected randomly among the

Fig. 1 Knapsack cotton picker



major varieties to make the study effective and precise. Care was taken to accommodate varieties used in all seasons such as winter irrigated, summer irrigated, short duration, medium duration and rain fed. One hybrid was also included for the study.

Development of Prototype

The prime mover (0.82 kW, 5,600 rpm) was mounted with the aspirator directly on the shaft. A polypropylene container of 25 litre capacity was fixed on the frame as the cotton collection drum. A circular cotton filter 100 mm diameter and 225 mm high, made from nylon mesh, was attached inside the collection drum vertically on a suitable flange to restrict the entry of cotton inside the aspirator. A 25 mm diameter PVC hose was fixed on top of the collection drum with a tank nipple as picks up pipe for a length of 1,200 mm. The eye of the impeller was connected with the bottom of the collection drum with a 75 mm diameter sealed duct. The backrest was provided with a cushion and belt to carry the unit easily and safely. The unit is shown in **Fig. 1**.

Optimization of Components

It is essential to optimize the various machine and operational parameters; namely pick up pipe diameter, filter type, filter height, capacity of collection drum and speed of aspirator which control the suction force. The pressure and the pressure head loss at the tip of the suction pipe were measured with a U tube monometer for different combinations of the above related parameters when the engine was held at various constant speeds.

Pick up Pipe Diameter

A lightweight PVC pipe was used as the pick up pipe to reduce frictional resistance and weight of the unit. The velocity and pressure of air flowing through the suction pipe was dependent upon the diameter. Hence, the diameter was required to be optimized with respect to the suction force necessary for pneumatic picking. The pipe diameters of 18 mm, 25 mm and 32 mm were adopted for all experiments.

Filter Type

A Suitable filter screen was required to restrict the entry of cotton into the aspirator and to allow only air to pass into the aspirator with less resistance between the collection drum and the aspirator. The net suction force depended on the type of screen adopted. Nylon mesh, aluminum perforated sheet and G.I. mesh filters were selected. The best filter was selected based on the pressure developed at the tip of pick up pipe.

Filter Height

The three filter heights used for the study were 150, 225 and 300 mm. Variation in the filter heights was necessary to accommodate the varieties in the height of the collection drum. The filter height was optimized by measuring the pressure created at the tip of the pick up pipe,

Capacity of Collection Drum

The three tested sizes of collection the drum were 15, 25 and 50 litre. The size was optimized by measuring the pressure created at the tip of the pick up pipe,

Speed of Aspirator

The four selected speeds were 2,500, 3,500, 4,500 and 5,500 rpm. The speed was optimized for its best performance by measuring the pressure created at the tip of the pick up pipe.

Table 1 ANOVA optimisation of componens of prototype

SV	DF	SS	MS	F
Treatment	80	5,582,373.988	69,779.675	121.03**
D (D)	2	181,897.673	90,948.836	157.74**
H (H)	2	1,011,231.414	505,615.707	876.94**
F (F)	2	907,991.191	453,995.596	787.41**
C (C)	2	568,049.377	284,024.688	492.61**
D x H	4	80,319.957	20,079.989	34.83**
D x F	4	87,084.457	21,771.114	37.76**
D x C	4	93,047.272	23,261.818	40.35**
H x F	4	462,455.383	115,613.846	200.52**
H x C	4	137,705.420	34,426.355	59.71**
F x C	4	666,080.586	166,520.147	288.81**
D x H x F	8	218,712.414	27,339.052	47.42**
D x H x C	8	49,932.377	6,241.547	10.83**
D x F x C	8	148,374.932	18,546.867	32.17**
H x F x C	8	302,289.451	37,786.181	65.54**
D x H x F x C	16	667,202.086	41,700.130	72.32**
Error	243	140,105.750	576.567	
Total	323	5,722,479,738		

CV = 2.6 %, ** = Significant at 1 % level, D = Pickup pipe diameter, H = Filter height, F = Filter type, C = Capacity of collection drum

Field Evaluation of Cotton Picker

The procedure for the determination of field capacity, picking efficiency, trash content, energy consumption and sound pressure were determined during field evaluation.

Field Capacity

The size of each plot was 3 x 5 m. The plots for the three experimental replications were randomly selected. The labourers were allowed to operate the machine (variety wise) for a known period of time. The weight of the seed cotton picked by the machine was analyzed in comparison with manual picking. The same procedure was repeated during three pickings (first picking, second picking and third picking). The field capacity was computed with the following formula.

$FC = W/T$,
where
FC = field capacity, kg/h,
W = weight of seed cotton, kg, and
T = time taken, h.

Picking Efficiency

The number of bolls in the plots selected for determining field capacity, including plots for replication, was counted before and after picking. The procedure was repeated for all three pickings (first picking, second picking and third picking). The picking efficiency was determined with the following expression.

$\eta p = (n_1 - n_2)/n_1 \times 100$,
where
ηp = picking efficiency, %,
n_1 = number of bolls present before picking, and
n_2 = number of bolls present after picking.

Trash Content

The trash content estimation was determined by using the trash analyzer in which the trash was separated when the cotton was fed through inlet after ginning. The trash content was determined by the following formula.

$T = (W_1/W_2) \times 100$,
where
T = trash content, %,
W_1= weight of trash separated, g, and
W_2= weight of cotton fed, g.

Table 2 Trash content

Sl. No.	Picker			Manual picking		
	P_1	P_2	P_3	P_1	P_2	P_3
1	10.70	12.76	15.61	3.01	5.81	6.87
2	8.02	12.98	14.57	1.58	4.73	5.94
3	10.31	12.07	13.89	1.37	3.98	6.34
4	9.18	10.79	13.19	2.11	5.76	6.31
5	8.79	9.91	12.61	2.06	5.34	5.78
Mean	9.40	11.70	13.97	2.03	5.12	6.25
SD	0.98	1.18	1.05	0.57	0.69	0.38

P_1 = First picking, P_2 = Second picking, P_3 = Third picking

Energy Consumption

A polar pacer heart rate monitor, which is a compact, portable instrument, was used in the field directly to measure the heart beat rate and, hence, the energy consumption during working of the cotton picker.

Sound Pressure

Sound is the sensation produced when longitudinal vibrations of the molecules in the external environment (alternate phases of condensation and rectification) strike the tympanic membrane. The speed of the sound wave increases with temperature and altitude. The amplitude of the sound wave can be expressed in terms of maximum pressure change or the root mean square of the pressure at the eardrum; but a relative scale is more convenient. The decibel scale is such a scale. The sound pressure was measured using an integrating sound level meter that measures in terms of decibel. The cotton picker was kept in a clean and quite environment free of air movement. The engine was started and the sound meter was held near the engine. At the maximum speed of the engine, the sound pressure in terms of decibel was noted.

Cost Economics

The material cost and fabrication cost of the unit was calculated based on the materials used and labour requirement for the fabrication of the cotton picker. The cost of operation per kg of cotton collected in each cotton picker was determined using the procedure recommended by RNAM test codes (Anon., 1995). This cost was compared with the cost of picking of one kg of cotton by conventional method. The savings in cost, time and energy with the picker was compared to the conventional method. The break-even point and pay back period also were

Fig. 2 Effect of pick up pipe diameter on pressure

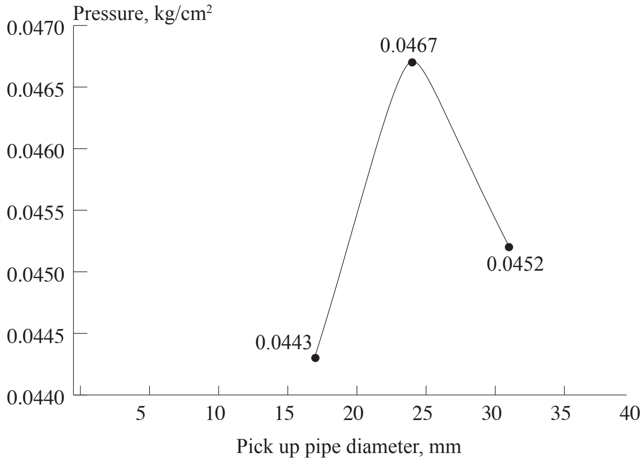


Fig. 3 Effect of filter type on pressure

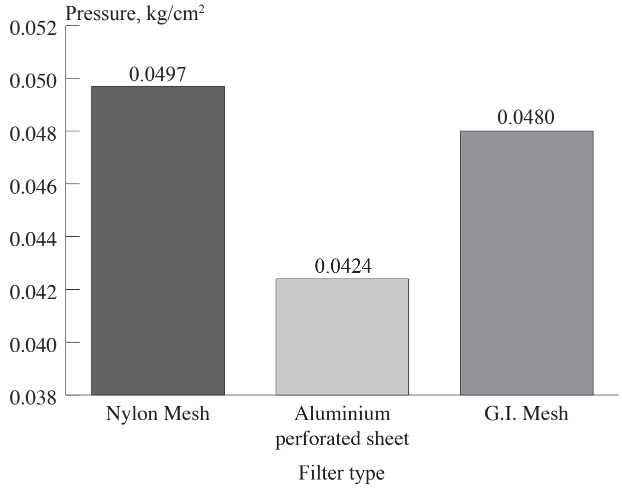


Table 3 Energy consumption and sound pressure

Sl. No.	Energy consumption, kCal/day		Sound pressure, db
	Picker	Manual picking	Picker
1	2,296	2,042	98.32
2	2,338	1,906	100.61
3	2,541	1,928	99.36
4	2,398	1,988	103.91
5	2,486	1,832	98.65
6	2,605	1,902	102.72
7	2,285	1,892	97.03
8	2,391	1,840	99.08
9	2,248	1,945	101.17
10	2,309	2,040	103.69
Mean	2,389.70	1,931.50	100.45
SD	112.96	69.80	2.25

computed for the each cotton picker.

Results and Discussion

Optimization of Components of Prototype

Pickup Pipe Diameter

Statistical analysis (Factorial Completely Randomized Block Design) showed that the variation in pick up pipe diameter had a positive correlation with pressure (**Table 1**). The maximum pressure was obtained with the 25 mm diameter pick up pipe as shown in **Fig. 2.**

The improved pressure in the 25 mm diameter pick up pipe may be due to drag coefficient during suction of seed cotton. In real action, the seed cotton is shrunk (squeezed) to about half of its projected area due to suction force on cotton which matches with the 25 mm diameter pick up pipe.

Filter Type

The effect of the three filters (nylon mesh, aluminum perforated sheet and G.I. mesh) on pickup pipe pressure is shown in **Fig. 3**. There was very strong correlation between the filter type and pressure in the pick up pipe. From **Fig. 3**, it is clear that the pressure of 0.0497 and 0.0480 kg/cm^2 are almost same for nylon and G.I. mesh. However, with the aluminum-perforated sheet, the pressure of 0.0401 kg/cm^2 was drastically lower. This variation among the filters may be due to the major variation in orifice configuration. Though the effects of the nylon mesh filter and G.I. mesh filter were close to the same on pressure, the nylon mesh was selected because of its light weight and its anti corrosive property. From the statistical analysis, it is also evident that the nylon mesh filter is the one best suited.

Filter Height

The effect of filter height on pressure showed statistical significance (**Table 1**). From **Fig. 4**, the maximum pressure was obtained at a filter height of 225 mm. Further increase of the filter height above the particular height might have created undue losses in suction (turbulence effect) due to abstraction at the top of the collection drum for free flow of air.

Capacity of Collection Drum

The variation in pressure with the capacity of collection drum is shown in **Fig. 5.** Statistical analysis showed that the variation in capacity of collection drum was correlated with the pressure in the pick up pipe. The capacity of the collection drum was optimized at 25 litre. Further increase in capacity of the collection drum led to operator stability problems.

Speed of Aspirator

The speed of the aspirator had a strong positive correlation with pressure in the pick up pipe (**Table 1**). This effect is shown in **Fig. 6.** The pressure in the pick up pipe increased with increase in the speed of aspirator. Thus, the optimum speed was 5,500 rpm.

Fig. 4 Effect of filter height on pressure

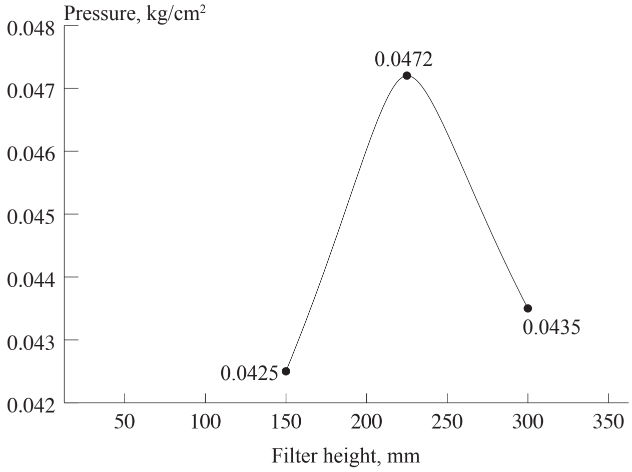
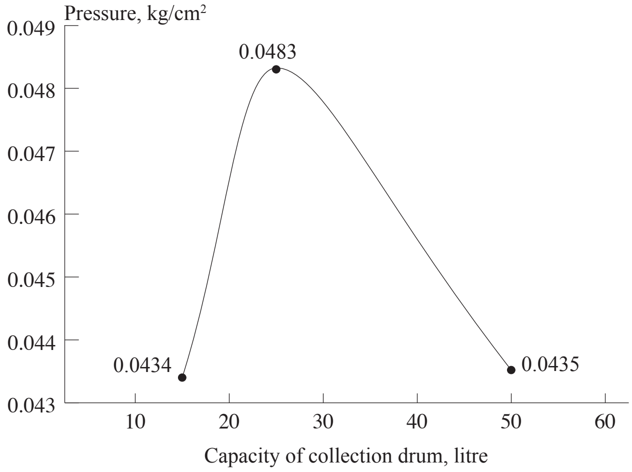


Fig. 5 Effect of capacity of collection drum on pressure



Field Evaluation of Picker

Field Capacity

There was a significant difference in field capacity of the machine compared to manual cotton picking. The increase in field capacity was about four times with the picker (one man labour). The field capacity increased with picking time. The third picking had more field capacity (5.07 kg/h) than first picking (4.93 kg/h). This may be due to more mature cotton bolls during third picking. The field capacity was highest with the P4 variety (5.20 ± 0.03 kg/h) followed by Anjali variety (5.14 ± 0.14 kg/h) and the lowest was with the Sumangala variety (4.85 ± 0.06 kg/h) followed by the Savitha variety (4.91 ± 0.05 kg/h).

Picking Efficiency

Manual cotton picking had maximum picking efficiency of 99.26 ± 0.23 %. The picking efficiency of the picking machine was highest with the MCU 12 variety (97.83 ± 0.15 %) and lowest with the Anjali variety (96.45 ± 0.20 %).

Picking efficiency increased with the time of picking, i.e., less in first picking (96.35 %) and more in third picking (97.48 %). This showed that the maturity aspect played a positive role in mechanised cotton harvesting.

Trash Content

The machine picking incorporated more trash content in comparison with manual picking. Picking time also influenced the trash content in seed cotton significantly. The minimum was 9.40 % in the first picking, 11.70 % in second picking and a maximum of 13.97 % in thethird picking as shown in **Table 2.**

Energy Consumption

The heart beat rate of the operator during the operation of the picker was recorded with a polar pacer heart beat monitor. The energy consumption is shown in **Table 3.**

Table 3 shows that there is only a small difference in energy consumption for manual picking and machine picking. The energy consumption for the picker was 2,389.70 ± 112.96 kcal/day, which is on par with the manual cotton picking (1,931.50 ± 69.80 kcal/day). The results are similar to the findings of Kumar and Parvathi (2001). The energy consumption for the knapsack cotton picker (2,389.70 ± 112.96 kcal/day) is on par with the knapsack sprayer in pesticide application, which is about 2,412.56 kcal/day. Hence, the operational strain (physiological cost demand) is same as pesticide application.

Sound Pressure

Generally speaking, the loudness of sound is correlated with the pitch, frequency and the amplitude of the sound wave. The greater the amplitude the greater the loudness and the greater the frequency, the higher the pitch. The sound pressure was measured with an integrated sound level meter and the values are shown in **Table 3**. From the table, the sound pressure for the picker was 100.45 ± 2.25 db which is well below the threshold auditory limit of the human ear of 140 db.

Cost Economics

The cost economics of the prototype was analyzed according to the RNAM test code and procedure for harvesters and is furnished in **Table 4.**

Conclusions

1. The pick up pipe diameter of 25 mm, nylon mesh filter, filter height of 225 mm, capacity of collection drum of 25 litre and speed of aspirator of 5,500 rpm were optimized.
2. The field capacity increased with the picking time. The third picking had more field capacity (5.07 kg/h) than first picking (4.93 kg/h). The field capacity was highest for P4 variety (5.20 ± 0.03 kg/h) and lowest for Sumangala variety (4.85 ± 0.06 kg/h).
3. The picking efficiency of the picker increased with the time of picking. The efficiency for the first picking was 96.35 % and, for

(continued on page24)

Fig. 6 Effect of speed of aspirator on pressure

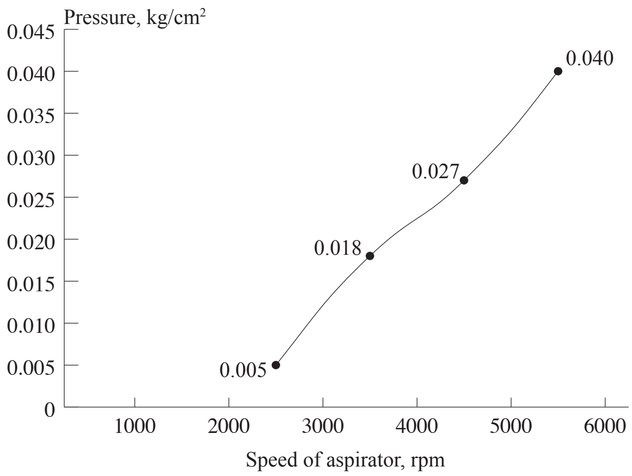


Table 4 Cost economics of picker

Sl. No.	Particulars	Picker
1	Cost of machine, Rs.	5,000
2	Cost of picking, Rs./kg	4.55
3	Saving in cost compared to conventional method, percent	9.00
4	Break even point, kg/annum	394.46
5	Pay back period, year	0.81
6	Saving in time compared to conventional method, percent	75.00
7	Saving in energy compared to conventional method, percent	68.23

Tractor and Implement Ownership and Utilization of Haryana

by
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Abstract

This study was conducted to ascertain the tractor utilization trends for different farm sizes in Haryana (India). Three districts were selected according to cropping patterns. The village that had the maximum number of tractors was selected from each block of the districts. Two hundred farmers owning new tractors were surveyed in the selected villages. Farms and framers were divided into four groups by farm size. The 10 ha and more group and the less than 4 ha group had the most farmers with 35 hp and higher tractors that were used for more than 1,000 hours per year. The 7-10 ha group had the most farmers that used tractors of 30-35 hp for 1,000 hours per year. No farmers with tractors of 25 hp or less used their tractor for more than 1,000 hours per year. The 4-7 ha group had the most farmers that used the 25 hp and less, and the 30-35 hp tractors, less than 400 hours per year. The 7-10 ha group had the most farmers that used tractors of more than 35 hp less than 400 hours per year. A disc harrow was owned by 98 % of the farmers in the state.

Introduction

The progress made by the farm sector in Haryana would not have been possible without the availability of farm machinery. The tractor is the main unit of farm machinery and ensures better quality of farm operations, timely completion of farm activities, better management supervision and dignity of labour.

Tractor population in Haryana increased from 4,800 (1966-67) to an estimated 200,000 in the year 2000-2001. Even the very small farms are purchasing tractors and other farm machinery. This is due to the fact that the farmers are not aware of the technical feasibility and economic viability of tractor use. In most cases, the choice of the tractor size is not according to land holding and workload.

A study was conducted in three different cropping regions to investigate the latest trends in tractor use for different sizes of farm. This study should enable engineers and other extension specialists to educate farmers of the need for a tractor that matches the size of their farm. The study was undertaken with the following objectives:

1. To study the tractor utilization trends at different farm sizes.
2. To study the ownership pattern of farm implements for different farm sizes.

Methodology

Haryana (India) state consists of 19 districts with three different cropping patterns; i.e. wheat-rice, wheat-cotton and wheat/mustard-legume/pearl millet. The study was carried out in three districts of Haryana, (Mohindergarh, Hisar and Kaithal), which represented the three different cropping patterns. All blocks from these three districts were taken into consideration and from each block one village was selected that had the most tractors. A total number of 19 villages were selected out of all blocks of the three districts. To investigate the farmer's attitude towards the utilization of farm tractor, a questionnaire was prepared to obtain the most possible information from the farmers through personal interviews. The information obtained included operational land holdings (farm size), name of tractor owner, make, model, power, cost of purchase, tractor use for personal and custom hiring, repair and maintenance cost, cost of operation, wages of the driver and cost of shelter. The farmers who purchased tractors in the last six years were selected at random. Two hundred farmers owning new tractors were surveyed. The collected data were closely observed and analyzed. The tractor owning farmers were classified into four categories according to their operational land holding size (1) less than 4 ha, (2) 4-7 ha, (3) 7-10 ha and (4) more than 10 ha. The data were analyzed to determining the average annual use by land holdings category.

Results and Discussion

Trends in Tractor Use for Different Farm Sizes

The breakeven point analysis showed that, to be economical, the annual use of tractors 25 hp or less, 30-35 hp and more than 35 hp should be 433.17, 416.15 and 436.84 hours per year, respectively. Utilization trends of different hp tractors at different categories of farm size is shown in **Table 1**. Small farms (less than 4 ha) had the most (5 %) tractors 25 hp or less with a use of less than 400 hrs annually, which was less than the economical breakeven point. These farmers were not interested in custom work. 2 % of these farmers had a tractor of more than 35 hp and used their tractor for more than 1,000 hrs annually. These were considered to have found adequate work and were above the breakeven point and were in the range of economical use. These farmers were very much interested in custom work to augment their income.

For medium farms (4-7 ha and 7-10 ha) most farmers (7.5 %) had 4-7 ha and a tractor size of 30-35 hp and used their tractor less than 400 hours annually, which was less than break-even economical point. This may be due to the fact that most of these farmers confine their machinery to their own farms. 3 % of the 7-10 ha farms with 30-35 hp tractors used their tractors for more than 1,000 hrs annually. These probably found adequate custom work and were in the range of economical use.

For large farms (more than 10 ha), a minimum number (0.5 %) that had tractors 30-35 hp and more than 35 hp used their tractor less than 400 hrs, which was less than the break-even point and were regarded as uneconomical. This was because these farmers had fewer tractor-operated implements. 2 % of the farmers that had a tractor larger than 35 hp used their tractor for more than 1,000 hrs annually. These could be considered to have found adequate work at their own farm and were regarded in the range of economical use.

In brief, it may be suggested that, while purchasing a tractor, the farmer should consider horse power and annual use of a tractor with proper consideration given to farm size and mechanized operation. To reduce the cost of cultivation/operation and to improve the economic condition of the farmer by the optimal use of tractor there is a dire need to encourage the custom hiring practice and popularization of modern machinery/implements among the farmers.

Implements Ownership with Respect to Farm and Tractor Size

The relationship between farm size and implement ownership is given in **Table 2**. The eight implements generally owned by the farmers were disc harrow, seed drill, cultivator, trailer, thresher, reaper and leveler. Of these, the disc harrow was most popular and was owned by 98 % of the farmers. The disc harrow was owned by all farmers with land farm size of 7-10 ha and more than 10 ha. Only 8 % of all farmers and 10.90 % of the farmers with farm size of more than 10 ha owned the tractor-operated harvester.

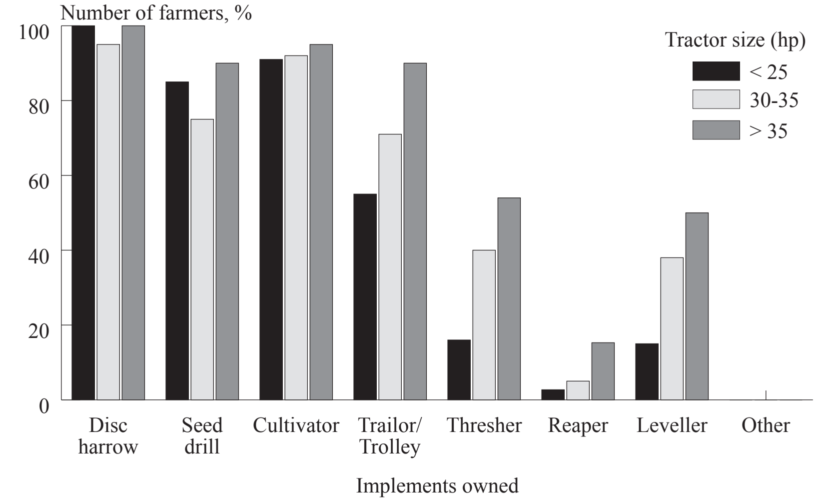
The relationship between tractor size and implement ownership is shown in **Fig. 1**. The disc harrow was owned by 100 per cent of farmers with tractors larger than 35 hp and 25 hp or less. Farmers with tractor size of more than 35 hp owned the most reapers (15.27 %) and farmers with a tractor size of 25

Table 1 Operational land holding size, tractor size and annual use of tractors in Haryana

Operational land holding size (ha)	No. of farmers surveyed	No. of farmers uses their ≤ 25 hp tractors in range of hrs.				No. of farmers uses their 30 - 35 hp tractores in range of hrs.				No. of farmers uses their ≥ 35 hp tractors in range of hrs.			
		< 400	400-450	450-1000	> 1000	< 400	400-450	450-1000	> 1000	< 400	400-450	450-1000	> 1000
> 4	47	10 (5)	1 (0.5)	1 (0.5)	-	7 (3.5)	2 (1)	12 (6)	2 (1)	1 (0.5)	2 (1)	5 (2.5)	4 (2)
4-7	51	11 (5.5)	1 (0.5)	1 (0.5)	-	15 (7.5)	3 (1.5)	8 (4)	2 (1)	-	3 (1.5)	5 (2.5)	2 (1)
7-10	47	4 (2)	3 (1.5)	2 (1.5)	-	2 (1)	3 (1.5)	11 (5.5)	6 (3)	4 (2)	-	9 (4.5)	3 (1.5)
> 10	55	-	1 (0.5)	2 (1)	-	1 (0.5)	-	15 (7.5)	2 (1)	1 (0.5)	4 (2)	25 (12.5)	4 (2)

Total No. of farmers surveyed = 200 (100)

Fig. 1 Relationship between tractor size and implements ownership in Haryana



hp or less owned the fewest reapers (2.7 %).

In brief, it may be suggested that farmers can improve the annual use of their tractors by having more tractor-operated implements.

Conclusions

1. 3 % of farmers with 7-10 ha and two percent of farmers with less than 4 ha, all with tractors of more than 30 hp, used their tractors for more than 1,000 hours annually. These farmers were interested in augmenting their income by doing custom work.
2. 7.5 % of farmers with 4-7 ha with tractor size of 30-35 hp, and 5 % of the farmers with less than 4 ha and tractor size of 25 hp or less used their tractors for less than 400 hours annually. These farmers had less interest in custom work.
3. The disc harrow was a very popular implement and was owned by 98 % of the farmers in the state. This was because most of the tillage work included the disc harrow.

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■■

Table 2 Operational land holding size and implements ownership in Haryana.

Operational land holding size (ha)	No. of farmers surveyed	Disc harrow	Seed drill	Cultivation	Tolley/ Trailor	Thresher	Reper	Leveller	Others
> 4	47	46 (97.9)	30 (63.8)	46 (97.9)	31 (66.0)	17 (36.2)	4 (8.5)	20 (42.6)	-
4-7	51	48 (94.1)	38 (74.5)	44 (86.3)	30 (58.8)	20 (39.2)	1 (2.0)	8 (15.7)	-
7-10	47	47 (100.0)	44 (93.6)	47 (100.0)	35 (74.5)	18 (38.3)	5 (10.6)	24 (51.1)	-
> 10	55	55 (100.0)	53 (96.4)	54 (98.2)	55 (100.0)	27 (49.1)	6 (10.9)	23 (41.8)	-
Total	200	196 (98.0)	165 (82.5)	191 (95.5)	151 (75.5)	82 (41.0)	16 (8.0)	75 (37.5)	

Figure shows in parenthesis indicate percentages

Study on Different Tillage Treatments for Rice - Residue Incorporation and its Effect on Wheat Yield in Tarai Region of Uttaranchal

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Abstract

Rice is one of the major crops grown in the Tarai region of Uttranchal occupying about 308,433 ha with a total production of 614,468 metric tonnes and a productivity of 1.9 tonnes/ha. The use of the combine harvester is more prevalent for harvesting rice and wheat. The presence of rice straw in the field, after combine harvesting, makes the subsequent tillage operation difficult. Such fields require more time and energy in seedbed preparation resulting in delayed wheat sowing. The general practice is to burn the straw, which is not eco-friendly. It also contains about 3 mg N g^{-1}, which is about half of the annual fertilizer requirement. This useful potential could only be harnessed by incorporating it into the soil.

A study to incorporate the rice residue efficiently with minimum tillage energy, was conducted for two years (2000-01 and 2001-02), which involved a combination of different tillage implements. The effect was observed on soil, machine and crop parameters including economics. The treatments were: T_1 - Disc plough x 1 + Harrow x 6 + sowing; T_2 - Chopping x 1+ disc plough x 1 + Harrow x 6 + sowing; T_3 - Disc plough x 1 + Harrow x 2 + heavy roller x 2 + sowing; T_4 - Rotavator x 2 + sowing; and T_5 - Harrow x 8 + plank x 3 + sowing (control).

The experimental results showed that there was only a small variation in wheat yields among treatments. Treatments T_4 and T_3 had the minimum cost of cultivation (8,537.20 and 8,550.88 Rs/ha, respectively) followed by treatments T_1, T_2 and T_5 (10,026.60, 10,326.03 and 10,622.30 Rs/ha, respectively). The net saving was maximum (30,053.52 Rs/ha) for T_3 and minimum (25,568.17 Rs/ha) for T_2. The benefit-cost ratio was also higher (3.51) for T_3. T_3 (Disc plough x 1 + Harrow x 2 + heavy roller x 2 + sowing) was the better package of practice for straw incorporation.

Introduction

Wheat is the world's most widely cultivated food crop. In India, it is the second most important crop, with rice being the first, and covers 25.1 million hectares of land. The total cereal crop production exceeded 208.8 million tonnes in 1999-2000, in which rice and wheat jointly contributed nearly three-fourths (36.16 % wheat, 42.82 % rice) of the total food grain production in India (Economic Survey 2000-2001). In major wheat growing areas of the country, rice-wheat is one of the dominant cropping sequences. Rice is one of the major crops and occupies about 37 percent (Economic Survey 2000-2001) of the total cropped area.

In northern states like U.P, Uttaranchal, Punjab and Haryana the traditional method of harvesting rice by using the sickle has largely been replaced by the combine harvester. This not only saves time and energy for the farmers but it also prevents the crop from being damaged due to natural calamities. The combine harvester has several advantages but one of the well-known disadvantages is the loss of straw that could otherwise be used as for fuel, feed and fiber. According to an estimate, on the average for every four tonnes of rice, nearly six tonnes of straw are produced, which shows a large amount of crop residue availability for disposal every year (Gupta, 1990).

This residue causes difficulty in preparing the seed bed for the wheat crop and requires a multiplicity of tillage operations. Most of the farmers eliminate the straw by burning it, which leaves a parched, scorched earth and a smoky atmosphere. In many developed countries, legislation limiting the burning of straw has been introduced in recognition of the air quality impact and the potential for increased adverse health effects such as incidence of asthma attacks. (Jenkins, 2000). The phase-down of rice straw burning over the next few years will require growers to gradually shift to alternative straw management practices. Other options are collection or incorporation of residue into the soil.

The collection of rice residue with field balers depends upon the market demand. The residue might be used as a feed or as industrial raw material. The cost of baling is very high due to high operating cost and poor recovery of straw (15-17 % of total dry matter) (Bamaga, 2000). This leaves only one alternative, which is to incorporate the rice residue into the soil efficiently and economically. The agricultural waste incorporated in soil increases the soil fertility substantially and, consequently, the production increases. The disadvantage is that it requires more tillage operations, requires more time and labour, delays sowing and increases cost of production.

In an intensive agricultural production system the time available for the seedbed preparation for wheat after harvesting rice is very limited. Therefore, seedbed preparation, which consumes considerable time and energy, should be completed within a short period under optimum soil moisture conditions by efficient tillage practices.

An effort has been made to use the above facts in this study of the combination of various tillage implements for incorporation of rice residue and its effect on wheat yield and the economics.

Methodology

The experiment was conducted during the year 2000-01 and 2001-02 at the Crop Research Centre of the university in a 0.30 ha combine harvested rice field. The soil was silty-clay loam with 4.80 % sand, 55 % silt and 30.20 % clay with 7.02 percent organic matter. The experiment had five treatments with three replications each (as shown below) in a completely randomized statistical design.

T_1 - Disc plough x 1 + Harrow x 6 + sowing

T_2 - Chopping x 1+ disc plough x 1 + Harrow x 6 + sowing

T_3 - Disc plough x 1 + Harrow x 2 + heavy roller x 2 + sowing

T_4 - Rotavator x 2 + sowing

T_5 - Harrow x 8 + plank x 3 + sowing - control

The technical specifications of the implements are given in **Table 1**. The size of plot was 30 x 6 meters. Before starting the tillage operation, the amount of residue available in each plot was determined. The residue (loose as well as root anchored stubble) was collected from 1m x 1m areas from three locations in each plot. The weight of the collected samples was determined and the amount of residue available on hectare basis was computed.

The percent residue incorporated was determined after the tillage operation by collecting and weighing the residue left on the surface, from 1m x 1m areas from three locations in each plot. The sample was collected, weighed and computed on a hectare basis. The following relationship was used to determine the percent rice residue incorporated.

$F = \{(Nb - Na)/Nb\} \times 100$, ...(1)

where,

F is the percent residue incorpo-

Table 1 Technical specification, cost of implements and their annual use with field capacity

Name of the implements	Technical specifications	Purchase price, Rs	Annual use, h	Useful life, years	Observed field capacity, ha/h
Harrow	Trailed type double action, 16 disc with 550 mm disc diameter	8,000	167	15	0.42
Rotavator	Indigenous make, 36 blades of L-shape, working width: 1300mm	48,000	300	8	0.21
Chopper	Overall length: 1500 mm; width: 1540mm; height: 860 mm, 3	25,000	200	10	0.67
Concrete roller	Length: 2500 mm; diameter: 500 mm and weight: 500 kg	8,000	357	7	1.25
Wooden plank	Length: 2200 mm, square section: 195 x 135 mm, weight: 50 kg	3,000	357	7	0.56
Disc plough	Mounted type with 2 bottom with, 600 mm disc diameter	10,000	167	15	0.23
Zero-till seed drill	9 rows, inverted-T fullow opener with adjustable row spacing	12,600	250	8	0.60
Tractor	Mahindra: 585DI, 3 cylinder, water cooled, 50 bhp	365,000	1,000	10	-

rated,

Nb is the amount of residue available before tillage operation, and

Na is the amount of residue available after tillage operation.

The initial and final soil moisture content and bulk density were also determined by taking samples from at least three locations in each plot before and after tillage. The standard technique was adopted for determination of initial and final soil moisture content as well as bulk density.

The clod mean weight diameter was determined for each prepared plot by adopting the standard sieve analysis method. The sample was collected from a representative area (30 cm x 30 cm) from each tilled plot. The soil sample was air dried, placed in set of sieves and shaken for about a minute. The geometrical mean of the clods retained on the top sieve, as well as the weight of the soil samples retained on each sieve, was determined. The sieve set had square holes of size 38.1, 25.4, 19.0, 12.7, 9.5, 4.8 mm. The clod mean weight diameter (CMWD) was determined by the following relationship:

$$CMWD = \sum_{i=1}^{n} (WiDi/Wi) \quad \text{................(2)}$$

where,

Wi is the weight of soil sample retained on ith sieve, g, and

Di is the clods mean size of the ith sieve, mm.

The fuel consumption and time required for each treatment in the tillage operation was noted separately for all the plots. The tillage operation was performed using a 50 bhp tractor. A stopwatch was used to determine the time and fuel consumption was determined with a specially made fuel-measuring device. The total tillage energy (TTE) for seedbed preparation was computed by considering the total time required, total fuel consumed and their energy equivalence with the following relationship.

TTE = 1.96 H + 56.31 FC, ...(3)

where,

H - Total human labour input, man^{-h}, and

FC - Total fuel consumed, l.

Wheat variety UP-2338 was sown at the rate of 120 kg/ha using a ferti-seed drill. Recommended doses of fertilizer, herbicide and other inputs were applied from time to time as per the agronomical requirements. Data pertaining to crop parameters (germination, tillering, final stand and wheat yield) were taken as per the standard procedure.

The economics of rice residue incorporation was determined by equations 4, 5 and 6 considering cost of operation of various tillage implements used in the study. The prevailing rate of diesel fuel, labour charges, and grain and straw was considered for computing the various costs.

NS = TR- TCP, ...(4)

TR = Pg Yg + Ps Ys, and ....(5)

TCP = CSBP + S + OI. ....(6)

where, NS = Net saving, Rs/ha; TR = Total return, Rs/ha; TCP = Total cost of production, Rs/ha; Pg = Prevailing cost of wheat grain, Rs/kg; Yg = Wheat yield, kg/ha; Ps = Prevailing cost of wheat straw, Rs/kg; Ys = Yield of wheat straw, kg/ha; CSBP = Cost of seedbed preparation, Rs/ha; S = Sowing cost, Rs/ha; and OI = Other inputs for wheat production, Rs/ha.

Table 2 Amount of residue available initially and after tillage operation

Treatments	Residue before tillage operation, t/ha			Residue after tillage operation, t/ha			Percentage Residue after tillage operation		
	2000-01	2001-02	Mean	2000-01	2001-02	Mean	2000-01	2001-02	Mean
T_1	6.53	4.98	5.76	0.130	0.170	0.150	1.99	2.00	2.00
T_2	6.04	5.56	5.80	0.072	0.073	0.073	1.19	1.61	1.40
T_3	6.05	6.45	6.25	0.100	0.110	0.110	1.65	1.53	1.59
T_4	6.82	5.45	6.14	0.118	0.160	0.139	1.73	2.55	2.14
T_5	7.31	6.40	6.86	0.150	0.160	0.155	2.05	2.55	2.30
CD at 5 %									0.0837708
CV									2.358729

Table 3 Soil parameters as obtained in different tillage treatments

Treatments	Soil moisture contents, % (db)						Bulk density, g/cc						Cold-mean weight diameter, mm		
	Initial			Final			Initial			Final					
	2000-01	2001-02	Mean	2000-01	2001-02	Mean	2000-01	2001-02	Mean	2000-01	2001-02	Mean	2000-01	2001-02	Mean
T_1	31.2	32.1	31.7	22.6	21.9	22.25	1.43	1.50	1.47	1.14	1.18	1.16	13.5	15.4	14.5
T_2	30.5	30.5	30.5	20.9	21.2	21.05	1.43	1.48	1.46	1.12	1.14	1.13	13.5	13.5	13.5
T_3	31.3	29.8	30.6	23.4	22.1	22.75	1.42	1.49	1.46	1.23	1.25	1.24	12.2	9.0	10.6
T_4	30.3	31.5	30.6	21.8	19.4	20.60	1.42	1.49	1.46	1.01	1.00	1.01	8.5	9.2	8.9
T_5	29.9	32.0	31.0	18.7	19.6	19.15	1.41	1.48	1.45	1.12	1.00	1.06	12.9	14.6	13.8
CD at 5 %												0.06462			0.30911
CV												3.06646			1.33990

Table 4 Direct tillage energy consumption in different tillage treatments

Particulars	Years	Treatments				
		T_1	T_2	T_3	T_4	T_5
Average time requirement, h/ha	2000-01	20.6	21.9	12.4	11.3	22.7
	2001-02	20.5	22.0	12.5	11.26	22.8
	Mean	20.55	21.95	12.45	11.28	22.75
CD at 5 % = 0.01387393, CV = 0.04143002						
Average fuel consumption, l/ha	2000-01	90.3	96.4	55.3	46.8	96.2
	2001-02	90.0	96.2	55.1	46.8	96.3
	Mean	90.15	96.3	55.2	46.8	96.25
CD at 5 % = 0.29754, CV = 0.2054913						
Human energy, MJ/ha	2000-01	40.38	42.92	24.30	22.15	44.49
	2001-02	40.18	43.12	24.50	22.07	44.67
	Mean	40.28	43.02	24.40	22.11	44.58
Mechanical energy, MJ/ha	2000-01	5,084.79	5,428.28	3,113.94	2,635.31	5,417.02
	2001-02	5,067.00	5,414.37	3,102.13	2,634.84	5,421.69
	Mean	5,075.90	5,421.33	3,108.04	2,635.08	5,419.38
Total tillage energy, MJ/ha	2000-01	5,125.17	5,471.20	3,138.24	2,657.46	5,461.51
	2001-02	5,107.18	5,457.49	3,126.63	2,656.91	5,466.36
	Mean	5,116.18	5,464.35	3,132.44	2,657.19	5,463.94

Results and Discussion

Amount of Rice-Residue Incorporation

The quantity of rice residue available before and after tillage was determined and has been presented in **Table 2**. On the average, about 6.0 tonnes of residue per hectare was available for incorporation. The highest percentage (2.30) of rice residue left on the surface after tillage was with treatment T_5 (control), where only a harrow was used to incorporate the residue. It was followed by treatments T_4, T_1 and T_3 with 2.14, 2.00 and 1.59 percent, respectively. The lowest percent, 1.40, of residue left was obtained with treatment T_2 where the residue was first chopped by chopper (stubble shaver) and then inverted with a disc plough. It is clear that chopping and inverting by disc plough was a better combination for incorporating the residue as compared to the other tillage treatments. On the average, only 1.89 percent of rice residue remained unincorporated, which indicates that the residue incorporation was effective in all the treatments. **Fig. 1** shows the rice residue incorporated in various tillage treatments. The residue left on the surface varied significantly for all the treatments at the 5 percent level.

Effect on Soil Parameters

Bulk Density

The initial and final bulk density was determined and has been presented in **Table 3**. The initial bulk density of all experimental plots had only a small variation and, on the average, was 1.46 g/cc. The bulk density was a little lower after tillage. It was minimum at 1.01 g/cc for treatment T_4. The final bulk density was higher for treatment T_3 at 1.24 g/cc and was followed by treatment T_1, T_2 and T_6 at 1.16, 1.13 and 1.06 g/cc, respectively. In general, the final bulk density was similar in all the plots, which is an indicator of similar tilth. The variation was significant for all the treatments at the 5 percent level. However, treatments T_1, T_2 and T_4, T_5 did not vary significantly with respect to each other.

Clod Mean Weight Diameter

The clod mean weight diameter was determined by sieve analysis and has been presented in **Table 3**. On the average, smaller clods (8.85 mm) were obtained in treatment T_4 where two operations of the rotavator were performed. This might have been due to better cutting and pulverizing action by the blades of the

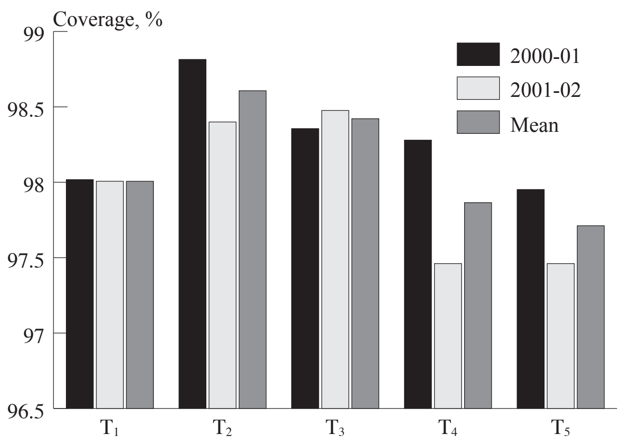

Fig. 1 Rice residue coverage

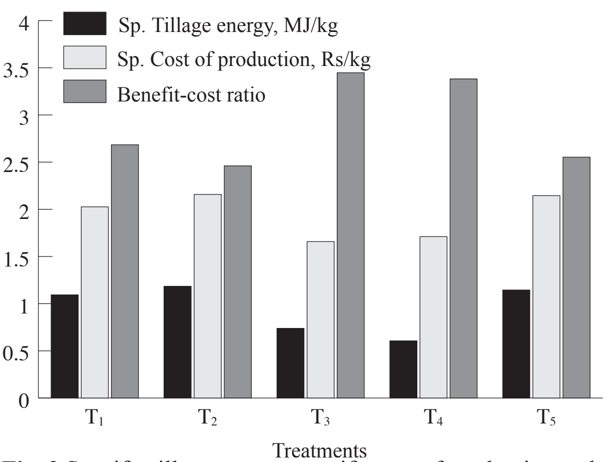

Fig. 2 Specific tillage energy, specific cost of production and benefit-cost ratio for different tillage treatments

rotavator. The clod size was larger at 10.6 mm for treatment T_3, 13.5 mm for T_2 and 13.75 mm for T_6. The largest clod size was 14.45 mm for treatment T_1. The clod size obtained in all the treatments was within the recommended values of 12 to 14 mm (Singh and Panesar, 1991) except for treatment T_3 and T_4. The reason for smaller size of clods in treatment T_3 may have been that the heavy roller assisted in breaking the clods. The value of CMWD varied significantly at the 5 percent confidence level for all the tillage treatments except treatments T_2 and T_5 where variation was not significant.

Time, Fuel and Tillage Energy Requirement

The time and fuel requirement for the various tillage treatments was determined for all experiments for the two years and the average values have been presented in **Table 4**. The average minimum time requirement was 11.27 h/ha for treatment T_4 where two operations of the rotavator were performed with the sowing operation. The maximum average time of 22.77 h/ha was obtained with treatment T_5 (control). The time required for treatment T_4 was about 50 percent less as compared to treatment T_5 that showed the rotavator to be an efficient tool compared to the harrow for seedbed preparation. It was followed by treatment T_2, T_1 and T_3 where the time requirement was 21.97, 20.57 and 12.48 h/ha, respectively. However, the difference in time requirement for treatments T_5, T_2 and T_2, T_1 was very small. As compared to T_5 (control), treatment T_2 required 3.51 percent less time and treatment T_1 required 6.14 percent less time than T_2 in seedbed preparation. Similarly, the difference in time requirement in T_4 and T_3 was also small. Treatment T_3 required about 11 percent more time than treatment T_4 . The time requirement in all tillage treatments varied significantly at the 5 percent confidence level.

The fuel requirements results have been presented in **Table 4**. The average minimum fuel requirement of treatment for T_4 was 46.82 l/ha followed by T_3, T_1, T_2 and T_5 at 55.18, 90.13, 96.27 and 96.3 l/ha, respectively. The fuel consumption was about 17.86 and 92.50 percent higher in treatment T_3 and T_1 as compared to treatment T_4. This indicated that treatment T_3 was more fuel-efficient for straw incorporation, after the rotavator, as compared to the other treatments. The fuel consumption in treatment T_3 was 17.86 percent higher than treatment T_4 where as, in comparison to T_3, the fuel consumption in T_5 (control) was 75 percent higher. This indicated that treatment T_3 was a better option for residue incorporation and sowing with respect to fuel consumption compared to other tillage options except rotavating twice. The total tillage energy input (**Table 3**) also followed the same trend. The fuel consumption varied significantly for all the tillage treatments at the 5 percent level of significance except treatments T_2 and T_5.

The direct tillage energy was determined for all the treatments and the result are presented in **Table**

Table 5 Crop performance as affected by different tillage treatments

Treatments	Germination count/m			Final stand/m			1000-grain weight, g			Grain yield, t/ha			Straw-grain ratio		
	2000-01	2001-02	Mean	2000-01	2001-02	Mean	2000-01	2001-02	Mean	2000-01	2001-02	Mean	2000-01	2001-02	Mean
T_1	39	44	42	82	73	78	53.5	39.6	46.55	6.29	3.95	4.93	1.34	1.39	1.37
T_2	41	45	43	84	67	76	58.9	37.4	48.15	6.34	3.18	4.75	1.35	1.37	1.36
T_3	38	42	40	82	72	77	59.5	37.6	48.55	6.32	3.57	5.14	1.34	1.32	1.33
T_4	36	43	40	77	74	76	58.6	42.0	50.30	6.28	3.78	5.03	1.29	1.35	1.32
T_5	41	41	41	82	73	78	56.3	39.3	47.80	6.22	3.80	5.01	1.36	1.36	1.36
CD at 5 %												0.13339			
CV												1.42572			

Table 6 Operational cost of the implements used for residue incorporation

Implements	Fuel consumption, l/h	Fixed cost, Rs/h					Variable cost, Rs/h					Total operational cost, Rs/h
		Depreciation	Interest	Insurance & taxes	Shelter	Total	Fuel cost	Lubrication	Repair & maintenance	Labour charge	Total cost	
Harrow	3.94	2.88	2.63	0.96	0.48	6.95	74.38	22.46	0.19	9.37	109.07	116.02
Rotavator	4.32	18.00	8.80	3.20	1.60	31.60	82.08	24.62	1.20	9.37	119.46	151.06
Chopper	4.11	11.25	6.88	2.50	1.25	21.88	78.09	23.43	0.75	9.37	113.83	135.71
Roller	3.10	2.88	1.23	0.45	0.22	4.78	58.90	17.67	0.19	9.37	88.32	93.10
Plank	2.08	1.08	0.46	0.17	0.08	1.79	39.52	11.85	0.07	9.37	63.00	64.79
Disc plough	5.65	3.60	3.30	1.20	0.09	8.17	103.75	31.12	0.24	9.37	146.67	154.84
Zero-till ferti-seed drill	3.21	5.67	2.77	1.00	0.50	9.94	61.00	18.30	0.38	9.37	91.23	101.17
Tractor	-	32.85	20.07	7.30	3.65	63.87	-	-	2.19	-	2.19	66.06

Cost of diesel fuel: Rs 19.00 per liter; Operators' wage: Rs 75.00 per day (8 hours)

4. Minimum average direct tillage energy (2,657.19 MJ/ha) was consumed in treatment T_4 (rotavator x 2 + sowing) and the maximum (5,663.94 MJ/ha) was for T_5. The energy consumed in treatment T_3 was 17.89 percent higher than treatment T_4. The conventional method of seedbed preparation (T_5) consumed 80.82 and 113.16 percent more energy as compared to treatments T_3 and T_4 respectively. This showed that treatment T_4 was an energy efficient package. The next to minimum energy consumption of 3,132.44 MJ/ha was for the treatment T_3. This also indicated that treatment T_3 was the better option as compared to other treatments except T_4.

The specific tillage energy was also determined and has been given in **Table 4**. Treatment T_4 required minimum energy to produce a unit weight of grain as compared to other treatments. It was followed by treatments T_3, T_1 and T_5. The highest specific energy consumption was found for treatment T_2. This, again, showed that treatments T_4 and T_3 are better options for producing a unit weight of grain over the other treatments.

Crop Parameters

Crop parameter data which included average germination count, average plant population at maturity, test weight, grain yield and straw-grain ratio have been presented in **Table 5**.

The germination count varied from 36 to 41 for the first year and 41 to 45 for second year. The average data for two years for the germination count from all treatments was 43 for the second year and 39 for the first year.

The final stand was 13.89 percent higher for the first year as compared to the second year. However, no definite trend was observed for the number of tillers at the maturity for all the treatments.

In general, the test weight of the first year was higher (57.4 g per 1000 grains) as compared to 39.2 g for the second year. The reason for lower test weight for the second year might be due to a sudden rise in daily mean temperature when the crop was at milky stage, which might have affected the setting of the grain.

The average wheat yield of the first year was higher (6.29 t/ha) as compared to 4.97 t/ha of second year. The low yield was due to lower test weight. However, in the year 2000-01, the yield was higher (6.34 t/ha) for treatment T_2 followed by 6.32 t/ha for T_3, 6.29 t/ha for T_1 and 6.28 t/ha for T_4. The lowest yield was 6.22 t/ha for T_5 (control). In the second year (2001-02) the highest yield was 3.95 t/ha for treatment T_3 and the minimum was 3.57 t/ha for T_1. For the two-year average, the highest yield was 5.14 t/ha for treatment T_3 and the minimum was 4.76 t/ha for T_2. Based on the yield, treatment T_3 was found to be the better package of practice as compared to other treatments. The yield of all treatments varied significantly at the 5 percent level. However, when variation in yields of treatments T_3, T_4 and T_4, T_5 were compared the variation was not significant.

Economics of Different Tillage Treatments

The operation cost of the implements used in the study has been presented in **Table 6**. **Fig. 2** shows the specific tillage energy, specific cost of production and benefit-cost ratio of various tillage treatments. The cost of production and the return cost for the various tillage treatments are presented in **Table 7**. Treatment T_4 had the minimum input cost (cost of cultivation) of 8,537.20 Rs/ha followed by treatments T_3, T_1, T_2 and T_5 that were 8,550.88, 10,026.60, 10,326.03 and 10,622.30 Rs/ha respectively. The specific cost of production was similar for treatment T_4 and T_3 at 1.70 Rs/kg and 1.66 Rs/kg and was maximum at 2.17 Rs/kg for T_2. The specific cost of production was 2.12 Rs/kg for the control.

The total net saving was maximum at 30,053.52 Rs/ha for treatment T_3 whereas it was minimum at 25,568.17 Rs/ha for T_2. The benefit-cost ratio was, again, found higher, for treatment T_3 (3.51) over the other tillage treatments. The minimum benefit-cost ratio of 2.48 was obtained for treatment T_2. This indicated that treatment T_3 was a better package of practice as compared to other tillage treatments for straw incorporation.

Table 7 Economics of different tillage treatments for production of wheat

Particulars	T_1	T_2	T_3	T_4	T_5
Cost of incorporation + sowing, Rs/ha	3,826.66	4,126.03	2,350.88	2,337.28	4,422.30
Other input, Rs/ha	6,200.00	6,200.00	6,200.00	6,200.00	6,200.00
Total cost of production, Rs/ha	10,026.60	10,326.03	8,550.88	8,537.20	10,622.30
Total return (grain + straw), Rs/ha	37,228.00	35,894.20	38,604.40	37,721.40	37,779.60
Net saving, Rs/ha	27,201.34	25,568.17	30,053.52	29,184.20	27,157.30

(i) Prevailing rate of wheat straw = 1.06 Rs/kg, (ii) Prevailing rate of wheat grain = 6.10 Rs/kg, (iii) Energy equivalence: (a) One adult labour = 1.96 MJ, (b) One liter diesel = 56.31 MJ/l

Conclusion

Treatments T_4 and T_3 were found to be better packages of practice for rice residue incorporation as compared to the other treatments with respect to time and fuel consumption, cost of incorporation and net saving. The straw incorporation was found satisfactory. Since the rotavator was a costly implement and was not very popular amongst the farmers and, also, in loose straw condition, there was often choking of the gang. Therefore, considering these facts, treatment T_3 (Disc plough x 1 + Harrow x 2 + heavy roller x 2 + sowing) was considered as the next best package of practice over the other treatments included in the study.

Acknowledgement

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(Continued from page14)

Optimisation of Machine Parameters of Pneumatic Knapsack Cotton Picker

third picking, it was 97.48 %. The picking efficiency was highest for MCU 12 variety (97.83 ± 0.15 %) and lowest for Anjali variety (96.45 ± 0.20 %).

4. The trash content was a maximum of 14.81 % in the third picking.
5. The energy consumption for the picker was 2,389.70 ± 112.96 kcal/day, which was on par with manual cotton picking (1,931.50 ± 69.80 kcal/day). The sound pressure for the mechanical picker was 100.45 ± 2.25 db.

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A Comparative Study on the Crop Establishment Technologies for Lowland Rice

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Abstract

Field experiments were conducted at Tamil Nadu Rice Research Institute, Aduthurai to test the performance of various machines used in rice cultivation. The performance of these machines was compared with the conventional method of paddy cultivation. Observations such as yield attributes, grain yield, and straw yield were recorded. Field capacity of the equipment and labour requirements for each operation were also recorded. The highest grain yield of 4.87 t/ha was recorded for the machine planting method which was on par with other establish methods such as paddy cum green manure seeding and manual planting. A field capacity of 0.20 ha/hr for machine planting was the highest. Also, machine planting gave the greatest labour saving of 25.32 percent over manual planting.

Introduction

Rice is the main cereal crop of India and is grown under varied agro-ecological situations. It is a key element in Indian food security. Cauvery delta zone is the potential area of rice cultivation in Tamil Nadu. Experience and experiments in all paddy growing areas have confirmed that higher yields can be obtained by transplanting as compared to direct seeding or drilling. Transplanted rice is considered the most meritorious (Alam, 1999). However, preparation of seedbed and transplanting at the right time with the desired plant density is not only expensive but also difficult to achieve on schedule with increasing wages. In addition, unavoidable drudgery is associated with manually transplanted rice. In order to avoid these problems mechanization was suggested. Mechanical transplanters are available that assure plant density and reduce drudgery. Mechanization strives to achieve timely field capacities and to achieve precision metering of seed, seedlings, fertilizer, pesticides and irrigation and, in turn, helps to increase productivity with reduced unit cost of production and to reduce drudgery for men and women who works in rice cultivation. Hence this study was conducted to evaluate the mechanized farming of rice cultivation in the Cauvery delta zone.

Materials and Methods

Field experiments were conducted at TRRI, Aduthurai under irrigated low land conditions during the kuruvai season of 2000 and 2001 with the short duration rice variety, ADT 43. The experiment was laid out in RBD with four replications. The treatment details were as follows:

T_1 = Direct sowing of paddy by

Fig. 1 Transplanter in operation

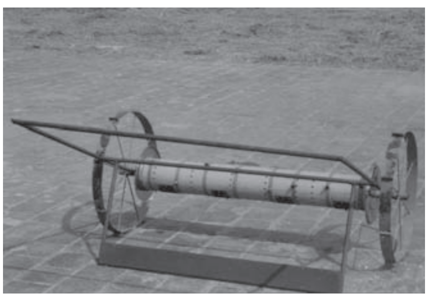

Fig. 2 Drum seeder

Fig. 3 Paddy cum daincha seeder

broadcasting followed by the usual methods of practice up to threshing

T_2 = Transplanting of seedlings by women followed by the usual methods of practice up to threshing

T_3 = Drum seeding of paddy + liquid urea applicator + weeder + Harvester + Thresher

T_4 = Paddy cum green manure seeder + weeder + Harvester + Thresher

T_5 = Transplanting by machine + Liquid urea applicator + weeder + Harvester + Thresher

The Chinese model power transplanter was used to plant the rice crop in eight rows using mat type nursery (**Fig. 1**). The 8-row drum seeder (TNAU model, **Fig. 2**) was used for seeding pre-germinated seeds on puddled soil with a row spacing of at 15 cm. The 6-row rice cum green manure seeder (TNAU model, **Fig. 3**) was used for seeding pre-germinated rice seeds and green manure seeds on puddled soil. The green manure was Daincha (Sesbania aculeata). Among the six rows, alternate rows were seeded with rice seeds. The space between two rows of rice was 25 cm. The green manure crop was trampled using cono weeder 30 days after sowing. In the manual planting method, the seedlings were transplanted at two seedlings per hill in line with a spacing of 15 x 10 cm. In the broadcasting method, the sprouted seeds were used for sowing at 100 kg/ha. For controlling of weeds, the pre-emergence herbicide, Butachlor, was applied at 2.5 l/ha on the third day after planting in transplanted rice (T_2 and T_5) and the eighth day after sowing in direct seeded rice (T_1, T_3 and T_4). One weeding was done manually in T_1 and T_2 treatments and by using a cono weeder in T_3, T_4 and T_5 treatments 30 days after sowing. The recommended application of fertilizers was applied.

Observations like number of hills/m^2, number of panicles/m^2 and number of grains/panicle were recorded. Labour required for each operation was recorded. The crop was harvested at maturity stage. Grain and straw yield were recorded. Harvesting and threshing were done as per the treatment details.

Results and Discussion

The various establishment methods markedly influenced the number of hills/m^2 (**Table 1**). Among the treatments, machine planting (T_5) recorded the highest number of panicles/m^2 (381) and was statistically on par with other methods of planting such as drum seeding (T_3), manual planting (T_2) and paddy cum green manure seeding (T_4). The lowest number of panicles/m^2 was recorded by the seed broadcasting method (T_1). There was no significant influence on number of grains/panicle during both the years of the study.

The highest grain yield of 4.87 t/ha was recorded with manual planting (T_2) but it was on par with machine planting (T_5), drum seeding (T_3) and paddy cum green manure seeding (T_4) which recorded grain yields of 4.85, 4.75 and 4.78 t/ha, respectively. The broadcasting treatment (T_1) recorded the lowest grain yield of 4.65 t/ha. Pandiarajan, et al (1999) reported that the highest grain yield was recorded with the line planting

(continued on page31)

Table 1 Effect of establishment method on population, growth and yield parameters of rice

Treatments	Number of hills, m^2	Number of tillers, m^2	Number of panicles, m^2	Number of grains, panicle
T_1	85	446	331	125
T_2	63	501	381	124
T_3	74	532	358	124
T_4	57	504	356	122
T_5	47	552	381	127
SED	2.1	7.3	14.7	4.8
CD (5 %)	4.7	15.8	32.1	NS

Pooled date: 2000 and 2001 Kuruvai (mean of four replication)

Table 2 Grain, straw yield, benefit-cost ratio and labour requirement under various treatment

Treatments	Grain yield, kg/ha	Straw yield, kg/ha	Benefit-cost ratio	Labour requirement, man hours/ha	Percentage of man-hour saving over transplanting
T_1	4,650	6,733	2.10	1,823	8.42
T_2	4,871	7,150	2.15	1,990	-
T_3	4,753	7,189	2.28	1,535	22.87
T_4	4,789	7,240	2.31	1,588	20.22
T_5	4,856	7,493	2.24	1,487	25.32
SED	48.6	66.4	-	-	-
CD (5 %)	105.9	144.7	-	-	-

Pooled date: 2000 and 2001 Kuruvai (mean of four replication)

Table 3 Field capacity of implements

Implements	Field capacity, ha/hr
Drum seeder	0.07
Paddy cum green manure seeder	0.06
Transplanter	0.20
Cono weeder	0.02
Liquid urea applicator	0.03
Harvester	0.12

Design of Tractor Operated Rotary Cultivator - a Computer Simulation

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Abstract

A rotary cultivator with 'L' type blades was designed and a computer program was developed to assist with the design calculations. The working width of the machine with the number of working sets were predicted for 30, 35 and 45 hp tractors by varying the forward velocity and the ratio of peripheral to forward velocity. Taking maneuverability into account, the optimum dimensions of rotary cultivator for each of these tractors were determined. The predicted values of working width, number of working sets and dimensions of the shaft and blade of a rotary cultivator were compared with the market available rotary cultivator for a 35 hp tractor indicating a maximum variation of ± 4.5 %.

Introduction

Use of improved implements and machines are required to bring about farm mechanization to increase the productivity of land. For preparation of a suitable seedbed, the plough and harrow are the two most important and widely used implements. But these two implements require more power and time resulting in a higher cost. With the introduction of reduced tillage systems, Indian farmers are inclined to use the rotary cultivator instead of conventional ploughs and harrows for preparing the seedbed. Use of the rotary cultivator started after World War II (Bernacki et al, 1972). This implement can be used for shallow tillage and for preparing the soil for sowing without using any other implements. However, no systematic design procedure for the rotary cultivator is available. Hence a study was undertaken at IIT, Khragpur to help researchers and engineers in designing the implement.

The direction of rotation, depth of operation and the ratio of rotor peripheral and forward velocity of the rotary cultivator are important from the design point of view (Hendrick and Gill, 1971a). Rotation conforming to the direction of travel of the machine is called concurrent revolution and opposite to the direction of travel is called reverse revolution. The concurrent revolutions produce a component of cutting force directed forward causing the machine to be pushed while reverse revolutions produce a pulling force (Bernacki et al, 1972). Moreover, the reverse revolution results in throwing the soil forward (Bok, 1965). Hence it is a common practice to use concurrent revolution for rotary cultivator.

The detail dimensions of the soil slice cut by a rotary cultivator are shown in **Fig. 1**. It has been conventional for the rotary cultivator to be operated at a depth, h, less than the rotor radius, R. But, this could be operated at higher depths with h > R. Matyashin and Zhurkia (1968) reported that with h < R, energy required for cutting with concurrent revolution was 10 to 15 % less than the reverse revolution. However, a reverse trend was reported for h > R. For shallow tillage depths (h < R), an increase in the depth of operation of a rotary cultivator increased the power requirement but decreased the specific power requirement when other operating conditions were constant (Furlong, 1956 and Hendrick and Gill, 1971). For deep tilling depths when h > R with concurrent revolution, the optimum diameter to depth ratio ranged from 1.1 to 1.4 for minimum values of the ratio of the cutting length to tilling depth, leading to less specific energy requirement (Grinchuk and Matyashin, 1969 and Hendrick and Gill, 1971b). Reducing the tiller diameter by half reduced the energy requirement by 24 %.

Higher ratios of peripheral velocity of the rotor to machine forward velocity (u/v) resulted in lower fluctuation in cutting angle with simultaneous lowering of the maximum cutting angle and also lowered the cutting resistance (Hendrick and Gill, 1971b and Bernacki et al, 1972). Bernacki et al (1972) also reported that the higher the ratio of u/v, the shorter the soil slice and the lower the peripheral force. The specific work, i.e. the work performed by the machine during one revolution of working sets referred to the volume of soil tilled at that time, was considerably higher than the specific work of the mouldboard plough and increased very quickly together with the speed of the machine at constant length of the soil slices. The resistance to cutting a soil slice by the knife shank is relatively high and was related to the dependence of the specific work on width, b, of the individual soil slices. Hence, for minimum cutting resistance, the width of cut of a single knife of the rotary cultivator should not be less than 10 cm (Bernacki et al, 1972).

Table 1 Values of C_o and α_u for rotary cultivator with 'L' type blade

Soil condition	Working depth, cm	Length of soil slice, cm	C_o	α_u, kg-sec^2/m^4
Tilled	10.0-15.0	6.0-15.0	2.5-3.5	400-500
Meadow	3.5-6.0	6.0-12.0	5.0-10.0	400-500
Meadow	6.0-12.0	6.0-12.0	3.0-5.0	400-600

Bernacki, et al (1972)

Materials and Methods

Taking the above findings into consideration, the rotary cultivator with 'L' type blades was designed, following the procedures given below:

(a) Assuming a tractor power, the PTO power was calculated taking transmission efficiency and power reserve as 0.86 and 0.8 respectively (Anon, 1997).

$N_c = BHP \times \eta_t \times \eta_r$, ...(1)

where N_c = power available at PTO, BHP = tractor rated power, η_t = transmission efficiency, and η_t = coefficient of power reserve.

(b) Assuming u/v and forward velocity, the peripheral force was calculated using the following equation:

$K_o = N_c / u = N_c / [(u/v) \times v]$ ......(2)

(c) The specific work, A, was calculated as proposed by Bernacki et al (1972) and is given below:

$A = A_o + A_B$, ...(3)

where $A_o = C_o \times k_o$ = static specific work, and $A_B = \alpha_u \times u^2$ = dynamic specific work, ...(4)

where k_o = specific soil resistance, C_o = coefficient of specific soil resistance, which varies with soil and blade type, α_u = coefficient of dynamic soil resistance, and u = peripheral velocity of the rotor.

The values of C_o and α_u are summarized in **Table 1**.

(d) The mean torque acting on the shaft, M, was calculated using the following equation

$M = A \times Z \times L \times h \times b_m / 2\pi$, ...(5)

where, Z = number of blades working in one plane, L = tilling pitch = $(v/u) \times 2\pi \times R/Z$, h = tilling depth, and b_m = working width of the machine.

(e) The mean torque on the shaft could also be calculated from the peripheral force assuming rotor radius, R, using the equation given below:

$M = K_o \times R$ ....(6)

Comparing the Eqns. (5) and (6), an expression for Ko was obtained.

$K_o = A \times Z \times L \times h \times b_m / (2\pi \times R)$
$= A \times (v/u) \times h \times b_m$ ....(7)

Assuming 'h', the value of b was calculated as follows:

$b_m = K_o / (A \times (v/u) \times h)$ ....(8)

(f) Assuming the width of each blade (b_l), the number of working sets 'I' was determined.

$I = b_m / (b_l \times 2)$, ...(9)

where b_l should not be less than 10 cm. The number of blades operating in one plane, Z = 2 to 3. The total number of blades in a rotary cultivator = I x Z x 2.

The arrangement of blades fixed to the disk of the shaft is shown in **Fig. 2**.

For attaining minimum fluctuation of the peripheral force, the arrangement of working blades on the

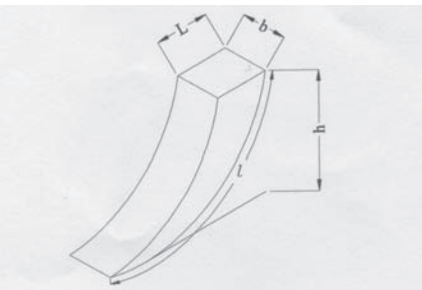


Fig. 1 Detail dimensions of the soil slice cut by a rotary cultivator

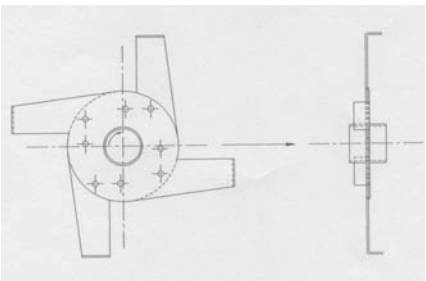


Fig. 2 Arrangement of blades fixed to the disk of the shaft

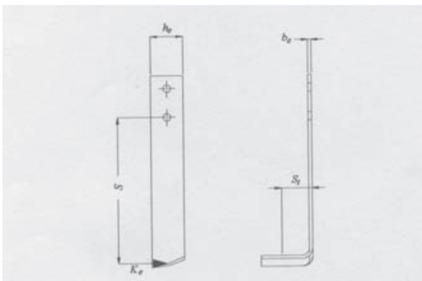


Fig. 3 Force acting on a single blade

drum was made that satisfied the following requirements.

i) Angular interval between individual working blades should be even to make the blades penetrate into soil individually in the same time interval.

ii) Interval between adjacent blades should be as large as possible to prevent clogging.

Hence, the angular interval between working blades was calculated as:

$$\Delta = \frac{360^o}{IZ_e} \quad \text{..................................(10)}$$

where Z_e = total number of tines in one set.

(g) Determination of shaft dimensions.

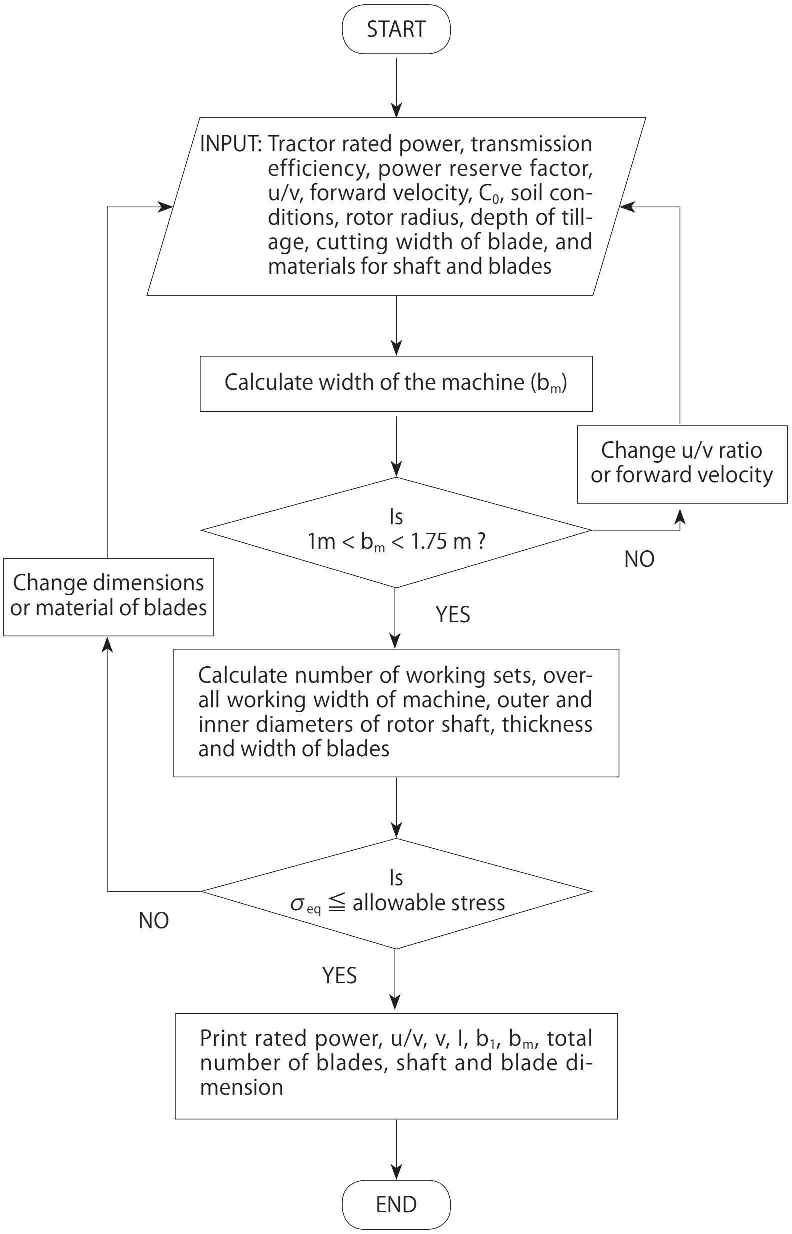
Because of the fluctuation in the peripheral force, an overload factor of C_s was used for calculating the peak peripheral force.

The design peripheral force, $K_s = K_o \times C_s$. The values of C_s = 1.5 for stoneless soil and 2.0 for stony soil. Peak moment on the drum shaft of the rotary cultivator,

$M_s = K_s \times R$. ....(11)

The shaft diameter was calculated

Fig. 4 Flowchart of the developed program



from the following equation.

$$\tau = \frac{16M_s}{\pi d_0^3(1 - t^4)} \quad \text{..........................(12)}$$

where τ = torsional stress and t = shaft inner diameter (d_i)/shaft outer diameter (d_o).

*(h) Determination of blade dimen*sions.

It is generally assumed that 1/4 of the number of blades in the rotary cultivator cut the soil simultaneously. The force acting on a single blade is shown in **Fig. 3**. These working blades, therefore, divided the peak force of the entire machines. Hence, the force K_e was introduced into calculation of a particular working element and was

$$K_e = \frac{K_s C_p}{IZ_e N_e} , \quad \text{..........................(13)}$$

where C_p = 1.5 for stoneless soil and 2.0 for stony soil, and N_e = fraction of the working blades operating simultaneously.

The blade shank of the rotary cultivator was subjected to bending and torsional stress. The force Ke is applied at a distance 'S' from the shank.

The bending stress,

$$\sigma_u = \frac{6K_e S}{b_e h_e^2} \quad \text{.................................(14)}$$

and the torsional stress,

$$\tau_t = \frac{K_e S_t}{2J/b_e} \quad \text{.................................(15)}$$

where J = polar moment of inertia.

The equivalent shear stress,

$$\sigma_{eq} = \frac{1}{2}\sqrt{\sigma_b^2 + 4\tau_t^2} \quad \text{......................(16)}$$

This stress σ_{eq} allowable stress of the material selected.

Based on the above procedure a computer program was written in Visual Basic to facilitate computations in determining the working width, number of working sets, shaft diameter and dimensions of the tines. The flowchart of the developed program is given in **Fig. 4**.

Results and Discussions

The specific work, working width and number of working sets for

30, 35 and 45 hp tractors with u/v ratio from 3 to 5 and forward velocity from 3 to 5 km/h are presented in **Tables 2**, **3** and **4** respectively. From these tables it can be seen that for a given tractor power and u/v ratio, the peripheral force available decreased with increase in forward velocity of the machine. Hence the working width of the machine reduced. However for the same tractor power, the working width of the machine further reduced when u/v ratio increased. This was due to reduction in peripheral force.

From maneuverability point of view the overall width of the implement should be within 1.75 m. Taking the above limitation into account, the u/v and v for 30, 35 and 45 hp tractors were found to be 5, 3; 4, 4 and 4, 4, respectively, which are indicated in the Tables with bold letters. Assuming 5 cm clearance between working sets, the predicted overall working width, B, of the machine was found to be 1.65, 1.35 and 1.75 m, for the 30, 35, and 45 hp tractors, respectively. The dimensions of rotary cultivator predicted for 35 hp tractors are compared with market available rotary cultivator in **Table 5**. From this table it can be seen that the dimensions are matching with a maximum variation of ± 4.5%.

Conclusions

The developed program was used to determine the working width, number of working sets, shaft diameter and dimensions of the blade of a rotary cultivator by suitable design assumptions. Taking maneuverability into account, the optimum dimensions of the rotary cultivator for the 30, 35 and 45 hp tractors were decided. The predicted dimensions matched with the market available rotary cultivator for the 35 hp tractor with a maximum variation of ± 4.5 %. Thus the developed program can be used as a tool for designing rotary cultivator for different horsepower ranges of tractor and soil conditions.

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Table 2 Rotary cultivator dimensions predicted for 30 hp tractor

u/v ratio	Forward velocity, V, km/h	Peripheral force, K_0, kg	Specific work, A, kg-m/m^3	Width of machine, b,m	No. of sets, I	Overall working width of machine, B,m
3	3	619.2	7,312.5	2.31	8	2.75
	4	464.4	9,500.0	1.33	5	1.65
	5	371.5	12,312.5	0.82	3	1.05
	6	309.6	15,750.0	0.54	2	0.65
4	3	464.4	9,500.0	1.78	6	2.15
	4	348.3	13,388.9	0.95	3	1.15
	5	278.6	18,388.9	0.55	2	0.65
	6	232.2	24,500.0	0.34	1	0.45
5	**3**	**371.5**	**12,312.5**	**1.37**	**5**	**1.65**
	4	278.6	18,388.9	0.69	2	0.85
	5	222.9	26,201.4	0.39	1	0.55
	6	185.8	35,750.0	0.24	1	0.35

Table 3 Rotary cultivator dimensions predicted for 35 hp tractor

u/v ratio	Forward velocity, V, km/h	Peripheral force, K_0, kg	Specific work, A, kg-m/m^3	Width of machine, b,m	No. of sets, I	Overall working width of machine, B,m
3	3	722.4	7,312.5	2.69	10	3.25
	4	541.8	9,500.0	1.56	6	1.85
	5	433.4	12,312.5	0.96	3	1.15
	6	361.2	15,750.0	0.63	2	0.75
4	3	541.8	9,500.0	2.07	7	2.45
	4	**406.4**	**13,388.9**	**1.10**	**4**	**1.35**
	5	325.1	18,388.9	0.64	2	0.85
	6	270.9	24,500.0	0.40	1	0.55
5	3	433.4	12,312.5	1.60	6	1.95
	4	325.1	18,388.9	0.80	3	0.95
	5	260.1	26,201.4	0.45	2	0.55
	6	216.7	35,750.0	0.28	1	0.35

Table 4 Rotary cultivator dimensions predicted for 45 hp tractor

u/v ratio	Forward velocity, V, km/h	Peripheral force, K_0, kg	Specific work, A, kg-m/m^3	Width of machine, b,m	No. of sets, I	Overall working width of machine, B,m
3	3	928.8	7,312.5	3.46	12	4.15
	4	696.6	9,500.0	2.00	7	2.45
	5	557.3	12,312.5	1.23	4	1.55
	6	464.4	15,750.0	0.80	3	0.95
4	3	696.6	9,500.0	2.67	9	3.15
	4	**522.45**	**13,388.9**	**1.42**	**5**	**1.75**
	5	418.0	18,388.9	0.83	3	1.05
	6	348.3	24,500.0	0.52	2	0.65
5	3	557.3	12,312.5	2.06	7	2.45
	4	418.0	18,388.9	1.03	4	1.25
	5	334.4	26,201.4	0.58	2	0.75
	6	278.6	35,750.0	0.35	1	0.45

Table 5 Comparison of rotary cultivator dimension predicted and available in the market for 35 hp tractor

Parameters		Predicted	Market available
Number of sets		4	4
Overall width, mm		1,350	1,290
Rotor shaft diameter,mm	Outer	108	110
	Inner	103	105
Rotor radius, mm		320	330
Cutting width of blade, mm		140	145
Thickness of blade, mm		6	6
Width of blade, mm		120	125

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(Continued from page26)

A Comparative Study on the Crop Establishment Technologies for Lowland Rice

method. AICRIP (1996) experimental results also supported the significance of the drum seeding method in enhancing the grain yield of rice. Machine planting (T_5) gave significantly higher straw yield of 7.49 t/ha. Seed broadcasting method (T_1) gave the lowest straw yield of 6.73 t/ha. The other treatments were comparable with each other in straw yield. The higher benefit-cost ratios of 2.31 and 2.28 were obtained with paddy cum green manure seeding (T_4) and drum seeding (T_3). The Benefit-cost ratio of machine planting (T_5) was 2.24. Manual planting method (T_2) gave a lower benefit-cost ratio of 2.15. Pandiarajan, et al (1999) also reported that the highest benefit-cost ratio was obtained with the transplanter as compared to manual planting.

The field capacity of the equipment is reported in **Table 3**. The transplanter had the highest field capacity of 0.2 ha/hr as compared to other implements.

Considering the labour requirement, machine planting (T_5) required only 1,487 man hours/ha of rice cultivation compared to 1990 man-hours/ha for manual transplanting (T_2). Drum seeding (T_3) and paddy cum green manure seeder (T_4) gave 1,535 and 1,588 man hours/ha, respectively, of rice cultivation. Machine planting (T_5) recorded a labour saving of 25.32 percent over the manual planting method.

Conclusion

Machine planting may be preferred for rice cultivation even though a higher grain yield of 4.87 t/ha was obtained in manual planting as compared to 4.85 t/ha in machine planting because of the labour requirement and benefit-cost ratio.

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Machine-Crop Parameters Affecting Performance of an Axial-Flow Soya Bean Thresher

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Abstract

A threshing unit was fabricated to study the effect of machine crop variables. A peg-tooth drum was used for the study. Four levels of drum speeds, three levels of feed rates and three levels of soya bean moisture contents were used for testing. The threshing efficiency varied from 98 to 100 %. The grain damage and grain loss were less than 1 and 1.5 %, respectively. The maximum power requirement was 2.29 kW at grain moisture content of 32.88 % and at the drum speed of 700 rpm. The feed rate of 720 kg (plant)/h and 600 to 700 rpm drum speed gave highest output capacity, highest threshing efficiency, lowest grain damage and lowest grain losses. This unit will be later used on an axial-flow soya bean seed combine harvester.

Introduction

Axial-flow peg-tooth cylinder threshers are widely used in Thailand. Some of them have been modified to be used with rice combine harvesters. Currently there are about 100,000 threshing units being used in the country. These threshers are used to thresh many kinds of grains such as paddy, mung beans, and, also, soya beans. Soya bean consumption each year in Thailand is increasing. To meet the increasing demand, Thailand must import soya beans. In 1993, the domestic need for soya beans was 611,000 tons and increased to 812,000 tons in 1998 (OAE, 1999).

The Thai government has given high priority to increased production of soya beans by encouraging farmers to increase the area under soya bean production. Use of mechanical harvesting of soya beans has been considered advisable because of the current agricultural labor shortage in Thailand for harvesting the increased area. The development of a soya bean combine harvester has, therefore, become of paramount importance. The threshing unit plays a key role in determining the performance of a combine harvester. Therefore, the objective of this study was to develop a suitable peg-tooth type threshing drum and optimize its working parameters by studying the effects of drum speed, and feed rate, moisture content on the threshing performance.

Literature Review

Several impact devices have been designed to evaluate the effect of impact velocity on soya bean seed quality (Cain and Holmes, 1977; Bartsch et al, 1979; Paulson et al, 1978). Cain and Holmes (1977) evaluated the impact damage to soya bean seeds as a result of a single high-speed collision with a steel plate. They concluded that impact damage is dependent on both seed moisture content and the velocity of impact. Bartsch et al (1979) reported that the threshing and conveying operations during harvest consisted of dynamic events often involving a large momentum exchange during collisions of seeds with machine components and other seeds. Paulsen et al (1978) stated that the common cause of damage in all grain-handling studies is the particle velocity immediately before impact and the rigidity of the surface against which the impact occurs. The percentage of splits and fine material increased as the impact velocity increased and the seed moisture decreased from 17 to 8 %. The seed that had low percentages of splits after impact, also, had a high germination standard.

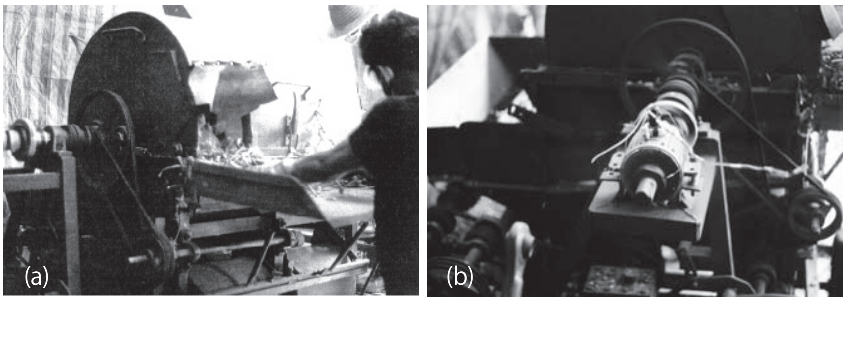
Nave (1979) reported that a seed

producer must be concerned with maintaining threshing and separating efficiency while avoiding undue impact damage to the seed. Efforts to reduce threshing damage while increasing capacity have resulted in the development of rotary threshing equipment. Newberg et al (1980) evaluated the damage to soya beans caused by rotary and conventional threshing mechanisms. Three different combines, a single-rotor machine, a double-rotor machine, and a conventional rasp-bar cylinder machine, were tested under field conditions at four peripheral velocities. The seed splits were significantly higher for the conventional cylinder than for the other two at similar peripheral speeds. The percentage of splits increased as the peripheral threshing speed increased for all three threshing mechanisms; however, the increase in splits was less with the rotary threshing mechanisms than the conventional cylinder threshing. The separation losses with the rotary combine were significantly higher at the slowest rotor speed. Dauda (2001) evaluated a manually operated cowpea thresher for small-scale farmers in northern Nigeria. The threshing efficiency was 84.1 to 85.9 % and seed damage was 1.8 to 2.3 %. Vejasit (1991) compared the performance of the rasp-bar and peg-tooth threshing drums of an axial flow thresher for the soya bean crop. The results indicated that the amount of grains retained on the threshing unit for both cylinders at all cylinder speeds and feed rates were not significantly different. Rani et al (2001) studied on a plot combine to thresh a seed crop of chickpeas. The maximum threshing efficiency was 97.2 % at 8.9 % seed moisture content and at 10.1 m/s cylinder speed. Mesquita and Hanna (1995) reported that the force required to open a soya bean pod was remarkably smaller than the force required to uproot plants and to detach pods from the stem.

Materials and Methods

This study was conducted at the Agricultural Engineering Division of the Department of Agriculture, Bangkok, Thailand. The soya bean threshing unit was developed by modifying the rice thresher that is normally used (**Fig. 1a**). The threshing unit consisted mainly of a commercially available main frame, tray, threshing drum, concave, separating and cleaning units, conveyor and a power drive unit. It operated on the principle of axial flow movement of the material. The threshing mechanism consisted of a threshing drum rotating inside a two-section concave. The threshing drum was of peg-tooth type having an open threshing drum. The diameter and length of the threshing drum were 420 mm and 930, mm, respectively. The concave was made up of a mild steel rod with rod spacing of 25 mm. The concave clearance between the threshing drum and concave was fixed at 40 mm. A tractor PTO powered the thresher and the tractor engine throttle set the speed. The power was transmitted to the threshing drum by V-belts (**Fig. 1b**).

Fig. 1 Soya bean threshing unit (a) and instruments for power measurement (b)



Four drum speeds, 400, 500, 600 and 700 rpm and three feed rates 360, 540 and 720 kg (plant)/h were used for testing. The four drum speeds were equivalent to a peripheral velocity of 8.80, 10.99, 13.19 and 15.39 m/s, respectively. Material was loaded onto the tray and fed into the threshing unit. The average moisture contents of grain (plant) used in this test were 32.88 (29.09) % (w.b.), 22.77 (18.72) % (w.b.) and 14.34 (16.78) % (w.b.). The most commonly grown soya bean variety, KKU-35, was used for testing. The crop was harvested by the traditional method. The moisture content of grain and plant was determined by the oven dry method (ASAE, 1983). The average grain-straw ratio of the crop was 1.23.

A proximity switch measured the threshing drum speed with a 1-tooth iron sprocket attached with the threshing drum shaft near the slip ring of the torque transducer. Threshing drum speed was measured by using a digital tachometer. In this experiment, the torque transducer with strain gage type KFG-2-350-D2-11 was used (**Fig. 1b**). A digital dynamic strain amplifier was used to amplify the output signals received from the transducer and they were recorded. A personal computer was used to control the instrument system, transfer and data analysis. The power requirement was calculated from the torque and speed data. All sensors were calibrated before the use.

The performance evaluation of the developed thresher was assessed in terms of output capacity, threshing efficiency, grain damage, grain losses and power requirement (RNAM, 1995). The performance of the soya bean threshing unit was analyzed at different moisture contents, drum speeds and feed rates by using a randomized complete block design (RCBD) of a 3 x 4 x 3 factorial experiment with three replications in each treatment. A comparison between treatment means was made by the least significant difference (LSD) at the 5 % level (Box et al, 1978; Gomez and Gomez, 1984).

Results and Discussion

Capacity

Figure 2 shows the effect of drum speed on capacity at different feed rates and moisture contents. The capacity rapidly increased with an increase in the drum speed for all feed rates and grain moisture contents. The maximum capacity was obtained at the highest feed rate of 720 kg (plant)/h, 14.34 % (w.b.) grain moisture content and 700 rpm drum speed. The capacity at a feed rate of 720 kg/h was higher than at other feed rates throughout the range of drum speeds and moisture contents tested. At the feed rate of 720 kg/h, the capacity at 14.34, 22.77 and 32.88 % (w.b.) grain moisture content increased from 143.80 to 214.17, 141.79 to 204.74 and 139.70 to 195.30 kg/h, respectively, (**Fig. 2**) as drum speed increased from 400 to 700 rpm. As feed-rate increased, capacity increased at all

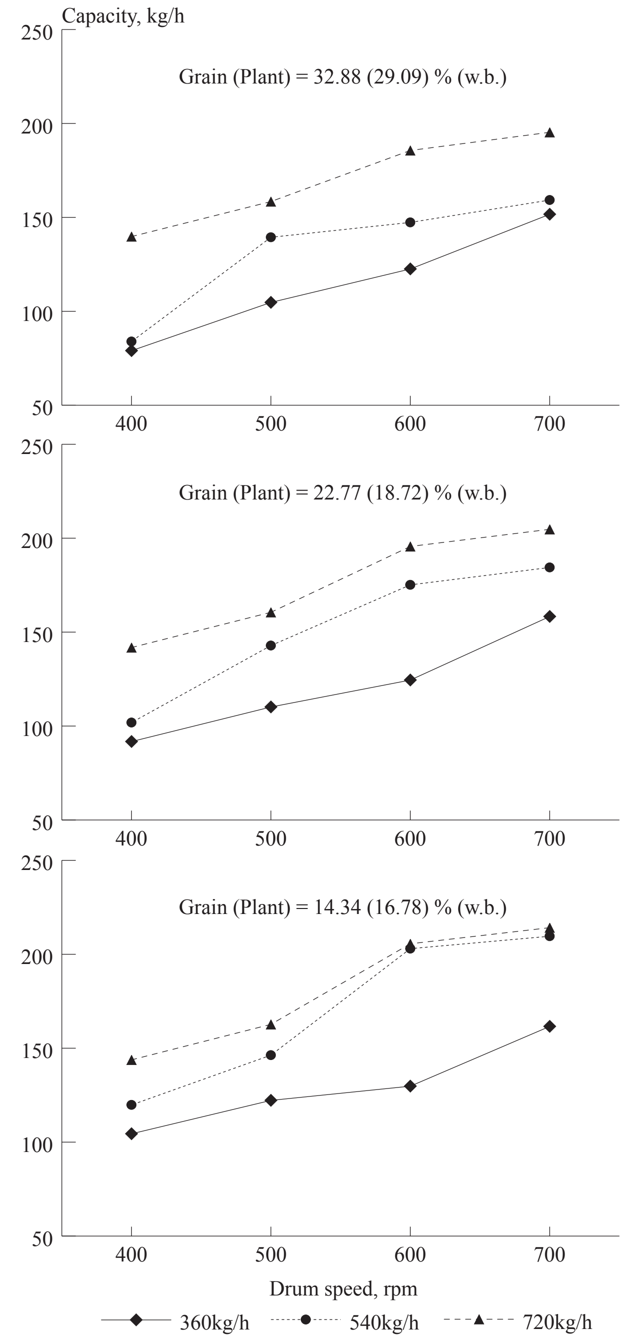


Fig. 2 Effect of drum speed on capacity at different grain moisture contents and feed rates

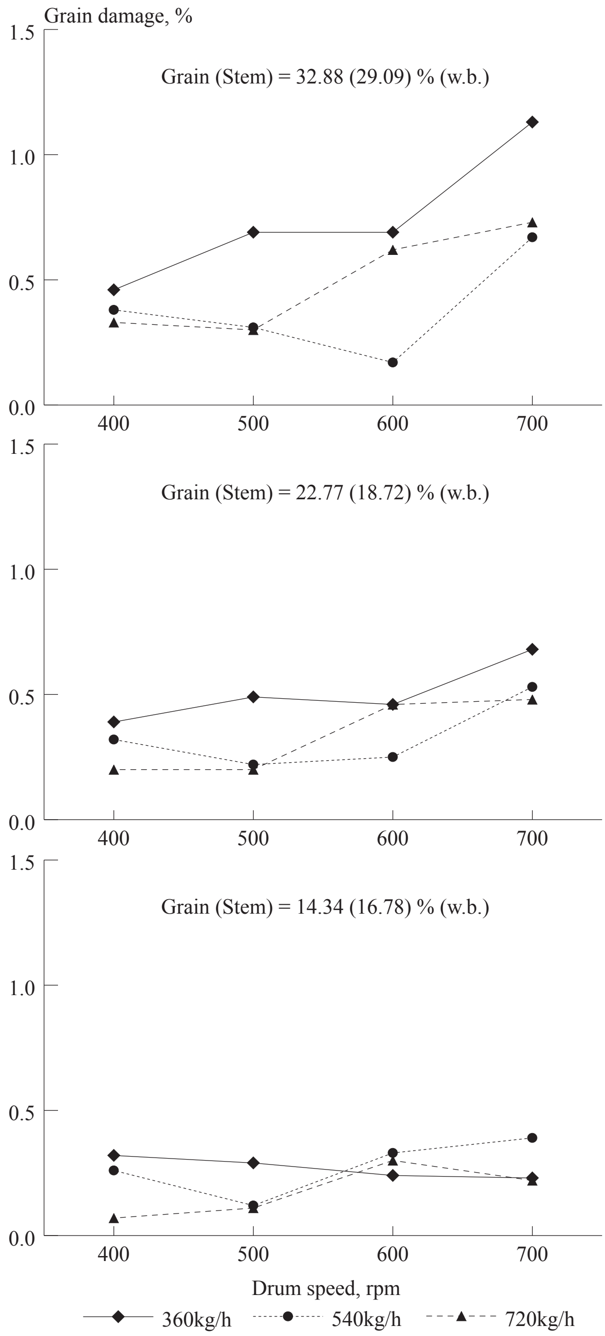


Fig. 3 Effect of drum speed on grain damage at different grain moisture contents and feed rates

drum speeds and moisture contents. The capacity at 500, 600 and 700 rpm gradually increased when the feed rate was increased from 360 to 720 kg (plant)/h at 22.77 to 32.88 % (w.b.) moisture content. At all feed rates and drum speeds, the capacity slightly decreased as the moisture content decreased.

The analysis of variance showed that the main effects of the moisture content (A), feed rate (B) and drum speed (C) were significant on the threshing capacity at the1 % level of significance (**Table 1**). The effect of drum speed and feed rate were the most significant. Among the first order interactions, moisture content and feed rate, along with feed rate and drum speed, showed highly significant effects on the thresher capacity. Comparison among treatment means using the least significance difference (LSD) showed that, at 720 kg (plant)/h feed rate, the capacity was not significantly different from the grain moisture content at14.34 and 22.77 % (w.b.). The capacity at 500, 600 and 700 rpm drum speeds was not significantly different when the feed rate was varied from 360 to 720 kg (plant)/h. The capacity at 540 and 720 kg/h feed rates showed a similar trend and was not significantly different at the drum speeds of 600 to 700 rpm.

Grain damage

Figure 3 shows the effect of drum speed on grain damage at different grain and stem moisture contents, and feed rates. The percentage of grain damage slightly increased with an increase in drum speed at 32.88 % (w.b.) grain moisture content for all feed rates. At 14.34 to 22.77 % (w.b.) grain moisture content, the grain damage was between 0.07 to 0.68 % for all feed rates and drum speeds. Grain damage slightly decreased with an increase in feed rate. Grain damage increased as the grain moisture content was increased from 14.34 to 32.88 % (w.b.). However, the grain damage was less than 1.5 % at all moisture contents, feed rates and drum speed combinations. The analysis of variance of the main effects of moisture content, feed rate and drum speed showed significant effects on grain damage at the the 1 % level of significance. Among the first order interactions, moisture content and feed rate, feed rate and drum speed, and moisture content and drum speed showed significant effect on the grain damage.

Threshing Efficiency

Test results indicated that threshing efficiency was between 98.35 to 99.49 % (**Fig. 4**). This was due to low pod cohesion at the range of soya bean moisture contents tested. This might have resulted in high threshing efficiency. **Table 1** shows that drum speed, feed rate and moisture content significantly affected threshing efficiency at the 1 %, 5 % and 5 % level of significance, respectively. Comparison among treatment means using LSD showed that, at 14.34 to 32.88 % (w.b.) grain moisture with 600 to 700 rpm drum speeds and a feed rate of 720 kg (plant)/h, the threshing efficiency did not differ significantly.

Grain Losses

Figure 5 shows the effect of drum speed on grain loss at different grain moisture contents and feed rates. Grain loss at 32.88 and 22.77 % (w.b.) moisture content rapidly decreased with an increase in drum speed from 400 to 600 rpm. But, it rapidly increased with further increase in drum speed from 600 to 700 rpm at all feed rates. At 14.34 % (w.b.) grain moisture content, grain loss slightly decreased with an increase in drum speed of 400 to 700 rpm. Grain loss rapidly increased with an increase in grain moisture content from 14.34 to 32.88 % (w.b.) at all feed rates. The grain loss was between 0.49 to 1.03 % when the drum speed was varied from 500 to 600 rpm at 14.34 to 22.77 % (w.b.) grain moisture content.

Table 1 shows that the effect of moisture content, feed rate and drum speed on grain loss were significant at 1 %, 5 % and 1 % levels of significance, respectively. The interactions between moisture content and drum speed on grain loss were also significant at the 1 % level of significance. Comparison between treatment means of grain loss showed that the grain losses did not differ significantly at grain moisture content of 14.34 and 22.77 % (w.b.) at 500 rpm and 600 rpm drum speeds.

Power Requirement

The power required for the soya bean threshing unit at different drum speeds, seed moisture contents and feed rates is shown in Figure 6. The power requirement of the thresh-

Table 1 ANOVA of the soya bean threshing unit performances

Source of variation	df	F-value			
		Capacity	Threshing efficiency	Grain damage	Grain loss
Replication	2				
Moisture content (A)	2	33.97**	3.92*	37.15**	52.03**
Feed rate (B)	3	217.56**	3.90*	16.11**	3.94*
Drum speed (C)	3	213.10**	58.78**	18.39**	25.93**
AB	6	4.77**	0.72 ns	4.51**	0.07 ns
AC	6	1.28 ns	1.32 ns	3.35**	3.13**
BC	9	6.00**	1.47 ns	2.85**	1.39 ns
ABC	18	1.31 ns	0.84 ns	0.99 ns	1.55 ns
Error	94				

**: highly significant an 1 % level, *: significant at 5 % level, ns: non significant, df: degrees of freedom ing unit increased as the speed of the threshing drum, feed rate and crop moisture content increased. These increases were due to greater compression of the material and increased friction between crop material and the threshing system. The average power requirement at 540 to 720 kg (plant)/h feed rates at 14.34 % (w.b.) grain moisture content was between 0.89 to1.85 kW when the drum speed was increased from 500 to 700 rpm (11.00 to 15.40 m/s). However, it was observed that the maximum power requirement was 2.29 kW at grain moisture content of 32.88 % and at a drum speed of 700 rpm.

Conclusions

a. The moisture content, feed rate and threshing drum speed affected the output capacity, threshing efficiency, grain damage and grain losses during soya bean threshing.
b. The capacity of the peg-tooth open threshing drum varied from 144 to 214 kg/h at all drum speeds and feed rates. The threshing efficiency was found to be in the range of 98.00 to 100 % for all

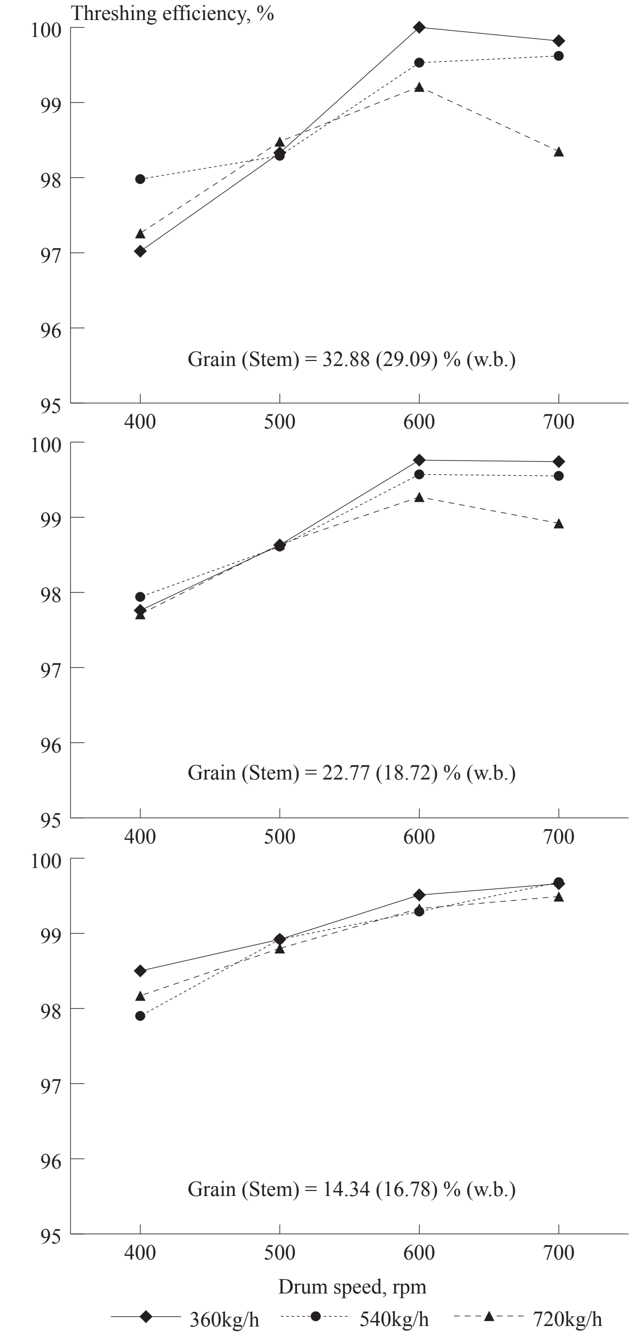


Fig. 4 Effect of drum speed on threshing efficiency at different grain moisture contents and feed rates

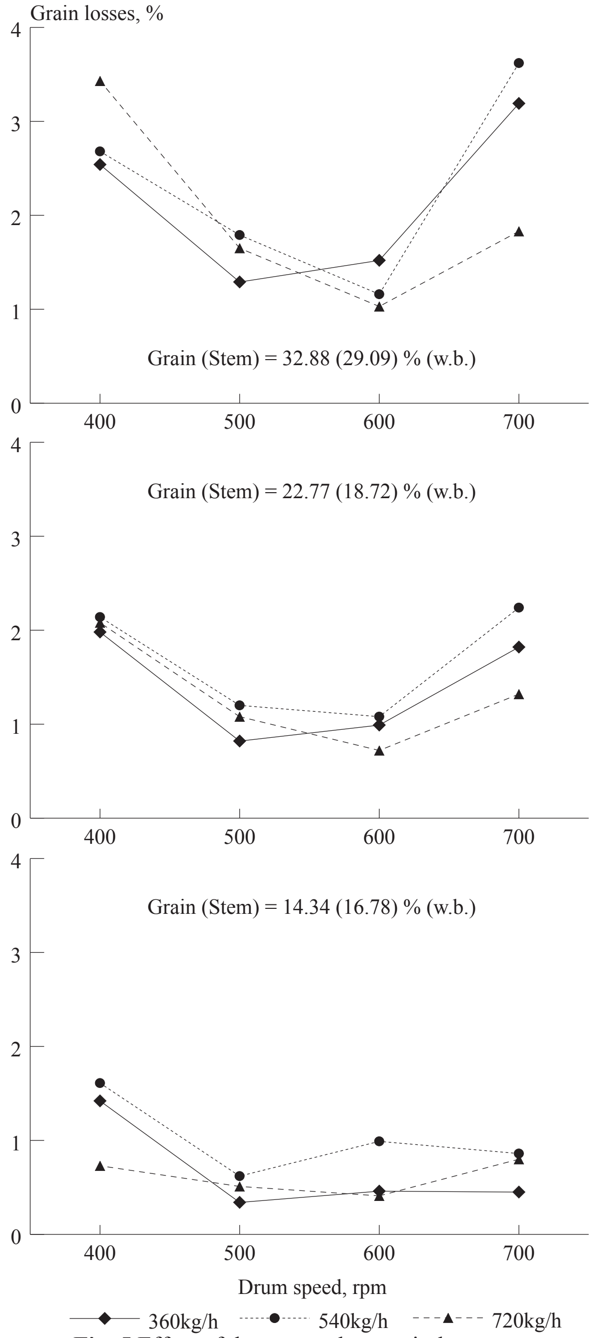


Fig. 5 Effect of drum speed on grain losses at different grain moisture contents and feed rates

moisture contents, feed rates with drum speeds varying from 500 to 700 rpm. The grain damage was lower than 1 %.

c. For better performance of the tested threshing unit, a peg-tooth drum at a speed range of 600 to 700 rpm (13.2 to 15.4 m/s) and a feed rate of 540 to 720 kg (plant)/h should be used. The output capacity, threshing efficiency, grain damage and grain loss at 700 rpm (15.4 m/s) drum speed and 720 kg (plant)/h feed rate were 214 kg/h, 99.49 %, 0.22 % and 0.80 %, espectively.

d. The average power requirement was 1.85 kW at feed rate of 720 kg (plant)/h, 14.34% (w. b.) grain moisture content and at a drum speed of 700 rpm (15.40 m/s).

e. For the design of a soya bean combine harvester with peg-tooth type drum, the speed should be in the range of 13.2 to 15.4 m/s. The grain moisture content should be in the range of 13 to 15 % during harvesting of soya beans by the combine harvester.

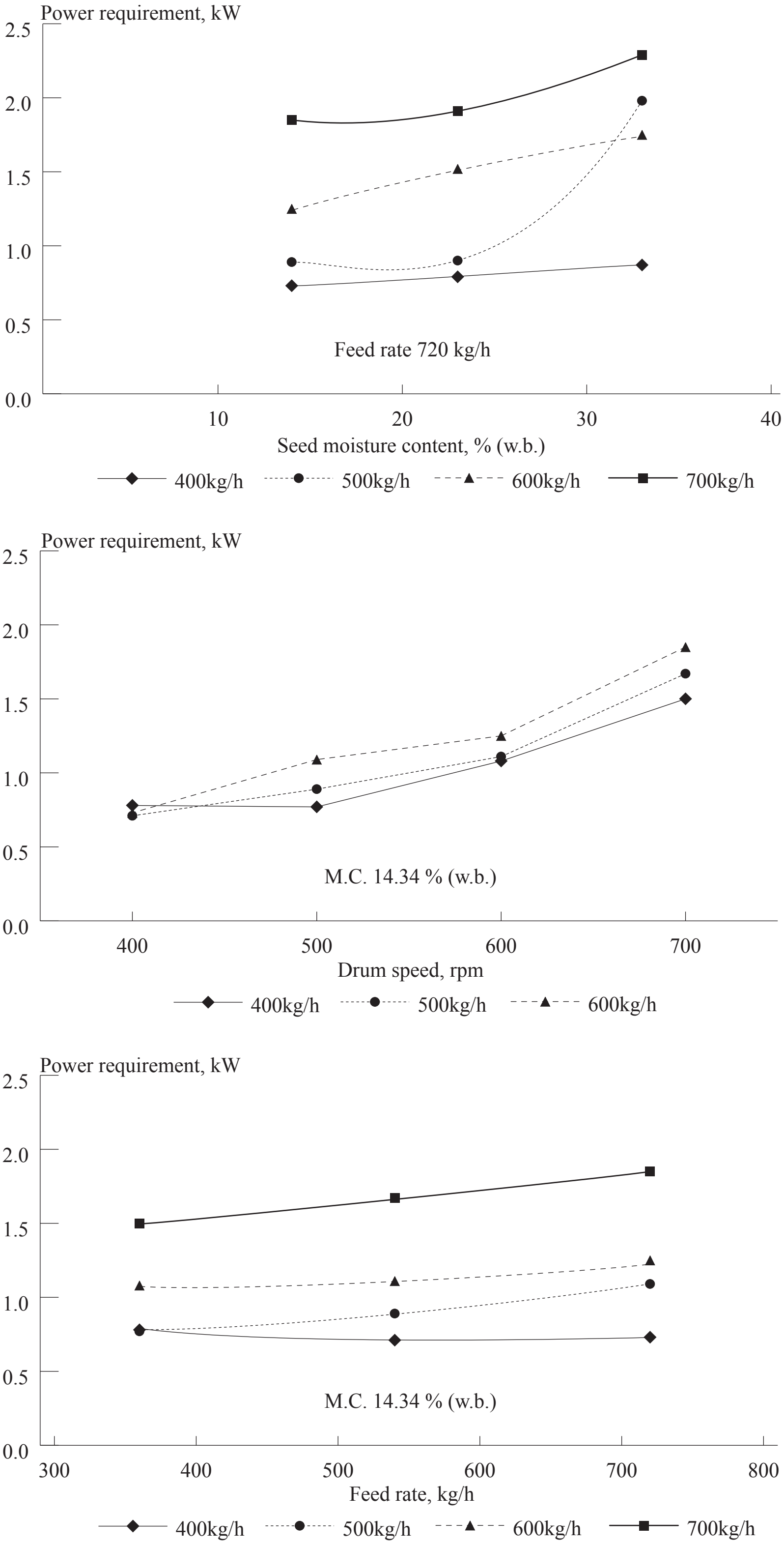


Fig. 6 Effect of drum speed, seed moisture content and feed rate on power requirement of a soya bean threshing unit

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Prospects and Problems of Power Tillers in Selected Districts of North Eastern Hilly Region in India - a Case Study

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Abstract

Use of power tillers is increasing in the North Eastern Hilly (NEH) region of India at a steady pace. It becomes imperative to study the performance and other important aspects related to the use of these machines with reference to the special topography and cropping patterns of these regions. With this objective, a survey has been conducted in three districts (East-Khasi Hills, Ri-Bhoi and Jaintia Hills) of Meghalaya State. The study involved information regarding farming practices, performance of the machine, type of operation being performed, average annual use including custom hiring, slope riding ability and various limitations due to the specific terrain and location. The results revealed that average annual hours of use (154 h) and command area (4-5 ha) of a power tiller were very low in the hilly region compared to the plains. There was little problem experienced in use of the machine in the fields of valley land of slope up to 6 percent. However, there was difficulty getting the machine to the fields because the approach roads have slopes up to 60 percent. Farmers using the power tiller were of the view that use of the machine resulted in more coverage of farming area by individual farmer and saving in labour and time. Also, there was additional income generation due to custom hiring practice by the owners of the power tiller.

Introduction

The farming systems of North Eastern Hilly (NEH) region of India are still of old traditional type where mostly local cultivation practices are followed and traditional crop varieties are cultivated. The main crop of this region is rice followed by maize, wheat and small millet. Other cultivated crops are gram, pigeon pea, groundnut, sesamom, castorseed and mustard. The food grain crops are usually followed by a permanent type of cultivation system in the lower valley lands and terraces. Wetland cultivation of rice is practiced widely in the terraces and lower areas of valleys. In the Meghalaya [4] state of India, a total area of 110 thousand ha was planted in rice with a production of 176.44 thousand tonnes with an average productivity of 1,604 kg/ha in 1995. This is much less than the national average of 1,930 kg/ha. Vegetable, orchard and horticultural crops are grown on the hill slopes. The region is rich in vegetables and orchard crops like potato, turmeric, ginger, tobacco, tapioca, citrus, pineapple, banana, pears and peach.

The region has not been able to catch up with the advanced practices from the point of view of mechanization. Some of the prominent reasons for this are the nature of terrain and the age-old shifting cultivation system that is prevalent here. Weak extension and promotional activities and improper marketing technology have kept the transition very slow. Shortage of farm power continues to

Acknowledgement: Authors are thankful to the district administrations of East Khasi Hills, Ri- Bhoi and Jaintia Hills Districts of Meghalaya State and the Headmen of different villages in these Districts for the cooperation and help rendered during the survey work quoted in this paper.

be a major productivity constraint. In some areas, mechanization of land preparation operations like tillage and puddling has been initiated. Now, power tillers have started penetrating the region for preparation of rice fields; thus, making the introduction of small, motorized machines in hill agriculture. Tractors and other farm implements are rarely used. Power tillers are used as a primary source of power in horticultural and other operations in addition to wetland cultivation. It is preferred due to its small size, ease of handling on the slopes, less space requirement for turning and low initial costs. **Table 1** shows the sale of the power tiller from 1990 through 1999 in the NEH region from which it can be seen that a definite number of machines are steadily flowing into the region every year.

The number of power tillers in the NEH region has been increasing at a steady pace. Accordingly, some of the traditional methods of cultivation have been changing. It is well known that an increase in the mechanical energy input in the farm leads to increase in production. A survey based on questionnaires and on visits to the farm was planned in order to study the use of power tillers in the three selected districts of Meghalaya state. Due to prevailing political situation in the region, the author was accompanied by a person chosen from the local area and the village headman during visits to the farmers' houses so that the work could be carried out without arousing suspicion in the mind of villagers. Sometimes movement from place to place was obstructed by inhospitable terrain and road conditions. The following are the objectives of the work.

Objectives

(i) To determine different uses of the power tiller in cultivation and other activities in the selected districts of Meghalaya and classify the farmers using power tillers based on the farm size
(ii) To determine ground slope and terrain conditions in the field and country roads where power tillers are used and transported
(iii) To determine the drudgery involved and difficulties faced by the farmers in operating the power tiller in the hilly terrain of Meghalaya

Methodology

A questionnaire was prepared for the proposed survey that would accomplish the objectives stated above. It included questions about the respondent such as land holding pattern and size, cropping pattern, and details of power tiller use. The questions on power tillers included various operations performed, facilities available for repair and maintenance, availability of spare parts, slope riding capability of the machine, difficulties faced during transportation, fuel consumption and details on custom hiring. A few questions were also incorporated on other potential uses of the machine and the socio-economic aspects related to machine use. This study was conducted in three hilly districts of Meghalaya state (**Fig. 1**). These are (I) East Khasi, (II) Ri-Bhoi and (III) Jaintia Hills. These districts have a comparatively higher concentration of power tillers and together they have almost 50 percent of the total machine population of the state of Meghalaya. Out of these three districts, 18 villages were selected for study. The total size of the sample was primarily based on the number of machines purchased in Meghalaya state per year.

Survey of respondents in the villages were selected from power tiller owners/users through the assistance of the Department of Agriculture of the Government of Meghalaya, local officials of the Indian Council of Agricultural Research and Headman of the selected village. Three to four farmers, who use the power tiller, were selected randomly. All the primary data were collected from the farmers by personal interview. Measurement of slope of land and slope of the most difficult approach to the field was taken following standard techniques and equipment. The collected data were classified and analyzed.

Results and Discussions

Meghalaya is one of the states where there are no records of land. Most of the hilly areas belong to tribal people, the clans and communities. The customary laws determine land ownership and individual

Table 1 Power tiller sales in the NEH region from 1990-91 to 1998-99

Name of the state	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99
Arunachal Pradesh	NA	NA	NA	NA	NA	NA	NA	NA	NA
Assam	528	695	149	489	301	1,996	1,997	1,083	1,621
Manipur	120	140	66	44	85	121	190	160	170
Meghalaya	40	40	20	85	70	60	60	70	50
Mizoram	NA	NA	24	5	15	Nil	NA	NA	33
Nagaland	16	12	23	5	7	Nil	25	NA	60
Tripura	132	274	189	190	200	213	267	688	313

NA: not available

Table 2 Land holding pattern of power tiller owners

Land holding pattern	Farmers owning power tillers, percent		
	Ri-Bhoi district	Jaintia Hills district	East Khasi Hills district
Marginal < 1 ha	72.1	90.9	87.5
Small 1-2 ha	10.5	10.1	12.5
Medium 2-4 ha	8.7	0.0	0.0
Large > 4 ha	8.7	0.0	0.0

rights. In some cases, individual possession of land is also granted for permanent cultivation. The existing system puts a serious restriction on the correct assessment of the land-based resources and cropping systems.

Socio-economic Conditions of Farmers

Information on land ownership of power tiller owners was analyzed and tabulated in order to relate to the pattern of use of the machine. Farmers are categorized according to the land holding into four groups; less than 1 ha, 1-2 ha, 2-4 ha and more than 4 ha. **Table 2** shows the percentage of farmers owning power tillers in each category.

It was noticed from the table that, in the Ri-Bhoi district, 72.1 percent farmers owned power tillers who had land holdings up to 1.0 ha. These farmers had a minimum area of land equal to 0.8 ha. Among others, 10.5 percent of farmers owned between 1-2 ha, 8.7 percent farmers owned 2-4 ha and 8.7 percent farmers had land more than 4 ha. In East Khasi Hills district 87.5 percent of the farmers with land between 0.8 to 1 ha and 12.5 percent of the farmers with land between 1-2 ha had power tillers. In Jaintia Hills district 90.9 percent of the farmers owning 0-1 ha of land and 10.1 percent farmers owning 2-4 ha of land owned power tillers. These figures reveal that in the hills, marginal and small farmers own most of the power tillers. There were only 2.6 percent of the farmers who had cultivable land more than 4 ha under their command and also owned power tillers. More small and marginal farmers are going for the power tiller because of incentive from the state government in the form of subsidy limited to small farmers. The other reason for the small farmers going for a power tiller is that they are taking it as an additional source of income also. However, the trend with large farmers was to give their lands on payment basis to the other small and marginal farmers of the same community. The farmers in this study who possessed more than 4 ha of land expressed that they are cultivating only a small fraction of the total land available to them.

Make and Model of Power Tillers

The information collected on the different makes of power tillers showed that 94.4 percent farmers in the Ri-Bhoi district were using the Kamco make, 6.8 kW (9 hp) Kubota brand power tillers and the remaining 5.6 percent were using the Khazana make 3.8 kW (5 hp) power tiller. In Jaintia Hills and East Khasi Hills district, all farmers had only the 6.8 kW (9 hp) Kubota brand power tillers. The reason for more Kubota power tillers in the area was because an authorized dealership of this machine was in Shillong, the state capital of Meghalaya state. **Fig. 2** shows the percentage of different makes of power tillers in the region.

Power Tiller Usage

Information was collected for the type of operations for which power tillers are used today. It was observed that every farmer using a power tiller utilized it for puddling operation just before transplanting of paddy. Some farmers made 2 to 3 passes of the machine for preparing the field. **Table 3** shows the percentage of farmers using the power tillers for different operations and the duration between two such operations.

The farmer's reaction on the use of the machine reveals that power

Fig. 1 State of Meghalaya in India and its districts

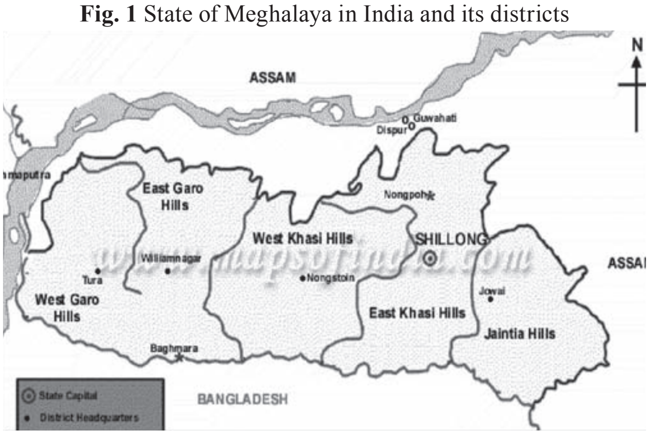
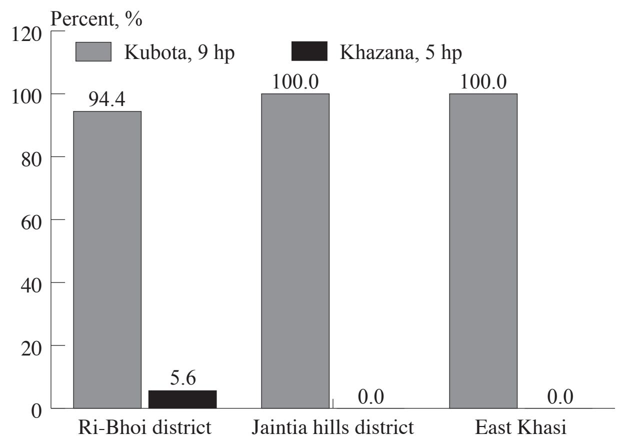


Fig. 2 Population of different makes of power tillers



tillers are being used for the field preparation of rice only, which is predominantly taken in the monsoon season. Some farmers are going for two tillage operations, the first time before the onset of rains and the second time just before transplantation of paddy in the field. **Table 3** above shows that 44.4, 62.5 and 66.7 percent farmers in Ri-Bhoi, East Khasi Hills and Jaintia Hills districts, respectively, are using power tillers for dry tilling operation also. This dry tilling is taking place in the month of February-March so that it can be left in this condition for some duration before the onset of rains in the month of April. Out of the total number of farmers surveyed, a major portion of farmers (75 and 100 percent in Ri Bhoi and East Khasi Hills Districts respectively) have a time gap of 2 to 3 months between two successive operations. In the Ri-Bhoi district 25 percent operated the power tiller within a period of two months only. It was surprising to note that only a few farmers (18 percent in Ri-Bhoi district, 12.5 percent in East Khasi Hills and 16.6 percent in Jaintia Hills), were using a leveler attachment with the machine. This leveler was a ladder made of bamboo on which the operator stood during operation. In all other cases leveling was done by either a manually operated wooden device called Khur or a ladder tied behind bullocks with a man stand in on it at the time of operation.

Use of Attachments with Power Tiller

The farmers were totally ignorant about other uses of matching implements like those for sowing, weeding and harvesting. About 100 percent of the farmers of East Khasi Hills and Jaintia Hill and 95 percent of the farmers of the Ri-Bhoi expressed that they were not aware of any equipment matching to the power tiller except the rotavator that is supplied as a standard attachment with the machine. Apart from the limited knowledge on the availability of the power tiller matching equipment, all the farmers were aware of the lug type puddling wheels. Moreover, nearly one-third (33.7 percent) of the respondents expressed that they do not want to use any power tiller attachment except the rotavator. About 43.2 percent of the farmers were of the view that, if a subsidy is available for the purchase of a matching implement, they would purchase it and the remaining (23.1 percent) said that they would purchase other matching implements on their own if available. Farmers wanted to use the power tiller for hauling on the tar-macadam road, but due to the lack of availability of a power tiller trolley and financial support for the purchase, they were not able to use their power tillers for transportation during off-season.

Annual Use of Power Tiller

The average annual use of the machines varied from a minimum of 54 hours to a maximum of 300 hours. Out of the total population of the farmers using a power tiller, 11.5 percent used it between 50 to 100 hours. A major portion of farmers using a power tiller (46.2 percent) had an annual use of between 100-150 hours. However, 26.9 percent of farmers used it between 150-200 hours. The percentage of farmers using the machine for 200-250 hours and 250 hours and more were 7.7 percent each. These facts are shown in **Fig. 3**.

Only 21.6 percent of farmers used power tiller for more than 225 hours. Average annual working hours by the power tiller were only 154 hours. This was due to small land holding size, irregular size of the plots and difficulties associated with hilly fields. For a 6.8 kW machine, farmers reported 8-9 hours of rotatilling operation to cover one ha of area. Usually farmers are in the practice of completing the bed in two passes. However, in a few cases, farmers reported having performed three passes for thorough mixing of weeds in the field. The survey revealed that the average area commanded by a power tiller varied from 4 to 5 ha, which is below the recommended figure of 6 ha.

Loading of the Power Tiller during Usage

All the 6.8 kW and 3.8 kW power tillers used in the region were powered by diesel engines only. The average fuel consumption of the popular 6.8 kW machine are tabulated in **Table 4**. It may be noted that the 6.8 kW Kubota model consumed up to 2.5 liters of diesel per hour while the 3.8 kW Khazana model consumed from 1.5 to 1.7 litre per hour at rated engine speed. Lower fuel consumption of these machines indicated that the machines were not fully loaded in the field.

It is observed from the table that the maximum number of the machines (a total of 59.5 percent of the sample size) had fuel consumption ranging from of 2 to 2.5 l/h. However, nearly 8.1 percent of the total farmers reported fuel consumption higher than 2.5 l/h. About 32.4 percent of the total farmers reported fuel consumption less than 2.0 l/h with machines less than two years old.

Custom Hiring

Custom hiring of the power til-

Table 3 Type of operation by power tiller and duration between two operations

Operation districs	Dry tilling	Puddling	Leveling	Duration between 2 operations	
				2-3 mouths	< 2 mouths
Ri-Bhoi	44.4	100	16.6	75	25
East Khasi Hills	62.5	100	12.5	100	0
Jaintia Hills	66.7	100	16.7	100	0

Table 4 Average fuel consumption of the 6.8 kW power tillers and their distribution

Fuel consumption	Districts		
	Ri-Bhoi district	East Khasi hills district	Jaintia hills district
< 2 l/h	59.9	0.0	12.5
2-2.5 l/h	38.8	72.7	87.5
> 2.5 l/h	0.0	27.3	0.0

lers was observed to be one of the additional sources of income for the owners of the medium and small land holding category of farmers. Hiring of power tillers was only for the rotatilling operations. In Ri-Bhoi and East Khasi Hills district 100 percent of farmers under study were hiring out their power tillers. In Jaintia Hills district about 63.6 percent of the farmers hired out their power tillers during the last year. This period of hiring varied from 90 to 150 hours depending on the demand in the vicinity of the areas. This is in addition to the use of machines in their own fields. The prevalent hiring rate varied from Rs.110 to Rs.250 per hour. The normal practice was to include the operator and fuel with the machine on custom hiring for an estimated average Rs.136 per hour.

Repair and Maintenance

The main problems faced by the farmers of Meghalaya state in operation and maintenance of the power tiller were the non-availability of spare parts and repair facilities for timely repairs at nearby places. Farmers had to rush to the state capital, Shillong, for even very small spare parts like fan belt and clutch wire. Due to lack of trained manpower, repair facilities were not available at the village level. Therefore, power tillers remained idle for days during the working season. Only one or two repair shops were spotted in the rural areas that cater to the needs of 15-20 villages. Thus, farmers must pay much higher prices for spare parts and repair charges due to lack of competition among dealers and repair shop owners. Moreover, farmers complained that the rate charged at the village level was sometimes very high as compared to that charged in the nearest larger market in Guwahati at a distance of 100 km. In the Ri-Bhio district, a majority of farmers (88.8 percent) got the required spare parts within a distance of 50 km, where as, in the Jaintia Hills spare parts are available at distant locations for the farmers (about 70 to 80 km). In East Khasi Hills nearly 62.5 percent farmers get spare parts within a distance of 50 to 75 km. The farmers of Jaintia hills district have expressed their satisfaction about the availability of repair and maintenance facility within a distance of 10-20 km and a majority of them are able to repair their own machines when the defects are of a minor nature.

Subsidy on Power Tillers

The information collected on the availability of different makes of power tillers showed that about 94.4 percent of the farmers in the Ri-Bhoi district were using Kamco make Kubota Power Tillers. The reason for more Kubota power tillers in Meghalaya was due to its authorized dealership, availability of spare parts and maintenance facilities. In addition, like other states of the country, the Government of Meghalaya was also providing a subsidy on the purchase of power tillers. The amount of subsidy, which was 25 percent (limited to a maximum of Rs.14,000) during 1985-86, has been increased to 50 percent at present and the upper limit was raised to Rs.54,000 per unit during the year 2000-01. However, the Govternment of Meghalaya has not been able to meet the subsidy requirements of the farmers of the State as more and more people have

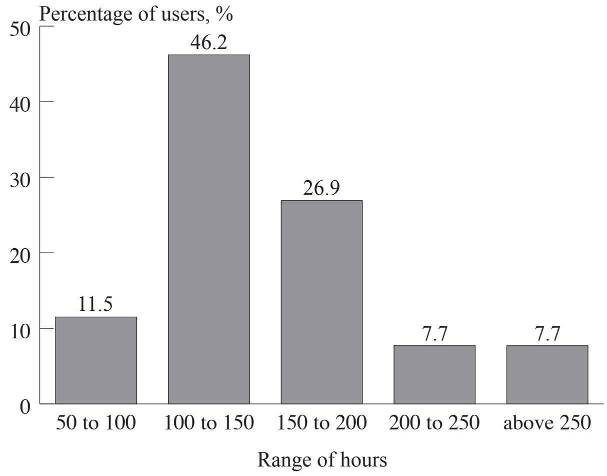


Fig. 3 Average annual use of the power tillers

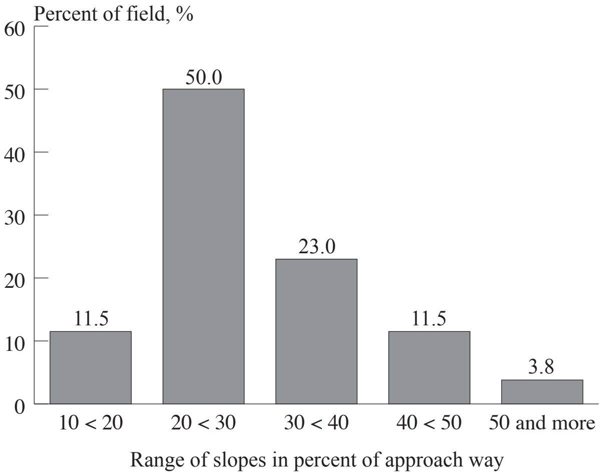


Fig. 4 Relationship between number of fields and slope of their approach way

shown interest. This situation was pushing a large number of farmers to go in for the purchase of power tiller even without subsidy.

Slope Negotiation Ability of Power Tiller

For studying the effect of topography on the performance of the machine, information was collected on (1) slope riding ability of the power tiller during transport and (2) maximum slopes the machines were capable of negotiating. Investigations on the type of field being used by the farmers for growing paddy revealed that the approach pathways up to the field had higher slope than the fields. Therefore, the main hurdle was in taking the machine to the field. The maximum slope of the field where the machine was used for puddling purpose was 6 percent, which is not a problem, and it was noted on 15.4 percent of the sample fields. All the remaining fields had lower slope.

Farmers maintain standing water in the field. However, there was a large variation in the slope of the approach to the field. Approach pathways to the fields were classified according to their slope into five ranges- 10 to 20 percent slope, 20 to 30 percent slope, 30 to 40 percent slope and > 50 percent slope. The number of fields accessed through pathways of different slopes are plotted in **Fig. 4**. There was hardly any field having 0 to 20 percent slope. It can be seen that 20 to 30 percent slope was most common. At this slope, it is already difficult to maneuver the power tiller. The highest slope observed was 76.9 percent where a power tiller was driven in reverse gear with precautions.

Drudgery of Operation

Information was also collected on drudgery perceived in the use of power tiller operation. This was collected for two different modes namely (1) for taking the power tiller up to the field and (2) during operation of the machine in the field. The response of Ri-Bhoi and Jaintia Hills farmers reflected that operation of power tillers while transporting through the approach pathway was moderately difficult. **Table 5** shows drudgery perceived during transportation and operation of the power tiller. In Ri-Bhoi district 66.7 percent of the farmers reported that both the field operation and transport of the power tiller were moderately difficult operations. However 11.1 percent farmers considered transport to be easy and 33.3 percent farmers considered the operation to be easy. At the same time, 22.2 percent of the farmers reported that transport was difficult and none reported that field operation was difficult. Thus, the farmers find transport of the machine more difficult than operation in field. In case of the other two districts, namely, Jaintia Hills and East Khasi Hills, the opinion of the farmers was similar. In Jaintia Hills district, 18.2 percent considered the field operations and transport moderately difficult, whereas, 81.8 percent said it was difficult. However, in East Khasi Hills district, 62.5 percent said it was moderately difficult and 37.5 percent noted it as difficult. In Jaintia Hills district, the field operation may be considered more difficult because of the lower stature height and less body weight of the farmers than those belonging to the other two districts.

About the use of seat on the power tillers, the opinion of the farmers was that, in the wetland, sinkage of the machine occurs while the operator is on the machine. Moreover, the use of a seat on the back side may prove to be dangerous on the hill slopes while negotiating the slopes.

Limitations of Use of the Machine

Under the present study it was observed that the power tillers were not being used for other operations like land leveling, transportation, water pumping, weeding, and as prime mover for thresher, seed drill and post hole digger. The reasons stated by the users were

- Non-availability of suitable matching implements
- Lack of knowledge about recently available machines
- Difficult terrain of the region
- Poor marketing network
- Weak financial status of the farmers
- Weak promotional and extension efforts

Conclusion

The following facts were obtained from the exhaustive survey conducted to assess the total performance of power tiller in the hilly region.

1. Average annual use of the machine was 154 h with a command area of 4-5 ha per machine as compared to the recommended 6 ha for the 6.8 kW power tiller.
2. All the farmers using the power tiller expressed that there was a saving of time and labour due to use of power tiller. Continuous operation was possible up to long

Table 5 Drudgery perceived during taking the power tiller to the field

Drudgery perceived	Number of farmers giving opinion, percent					
	Ri-Bhoi district		Jaintia hills		East Khasi hills	
	Transport	Operation	Transport	Operation	Transport	Operation
Easy	11.1	33.3	0.0	0.0	0.0	0.0
Moderately difficult	66.7	66.7	18.2	18.2	62.5	62.5
Difficult	22.2	0.0	81.8	81.8	37.5	37.5

working hours in the season of transplanting.
3. The farmers were of the opinion that more coverage area was possible with the use of the power tiller and there was additional income with the use of the machine due to custom hiring.
4. Farmers expressed that there was not much problem in use of the machine in the valley lands having slope up to 6 percent but, while transporting, it was more difficult to get the machine to the fields since the approach roads had higher slopes, even up to 60 percent.
5. There was a common opinion among the users of power tillers that use of a seat may lead to frequent sinkage of the machine and prove to be unsafe on the slopes during transportation.

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Design and Development of Cylinder Type Cotton Pre-Cleaner

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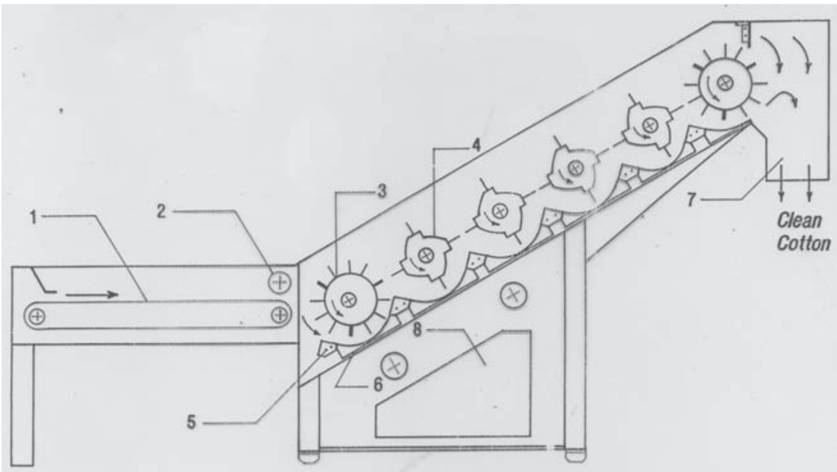
Abstract

Cotton cleaning before ginning is an important unit operation to retain quality of lint. Central Institute for Research on Cotton Technology (CIRCOT) has developed an inclined type cylinder cleaner to improve the lint quality by removing the trash. The inclined type cylinder pre-cleaner with 6 cylinders having a working width 1,240 mm was designed. Spiked and fan type beating cylinders were used to clean the seed cotton. A horizontal lattice feeder was provided for feeding the seed cotton to the cleaning cylinders. The developed cleaner was evaluated for its performance. The cotton varieties selected were LRA.5166, NHH.44 and H.4, which are commonly grown. The seed cotton of Super and Fair Average Quality (FAQ) grade was taken for the study. The cotton cleaning capacity of the pre-cleaners was found to vary from 2,760 kg/h to 3,156 kg/h with an average output capacity of 2,941 kg seed cotton/h. The cleaning efficiency was found to vary from 11.9 % to 26.5 %. The overall cleaning efficiency of the developed pre-cleaner was observed to be 20.2 %. An overall increase of 3.25 % in ginning output and 1 % increase in ginning percentage (GP) was resulted by cotton cleaning before ginning. No adverse effect of the pre-cleaner was observed on the fibre properties. The degree of

Fig. 1 Cylinder type inclined cotton pre-cleaner



1. Feed conveyer lattice, 2. Pressure roller, 3. 9-row spike & 3 blade cylinder, 4. 4-row spike fan type beater, 5. Cross rails, 6. Woven wire mesh, 7. Delivery mouth for cotton, 8. Trash chamber

whiteness (Rd) of lint was improved considerably resulting in grade improvement. The pre-cleaner was found to be commercially viable and its design was well accepted by the ginneries.

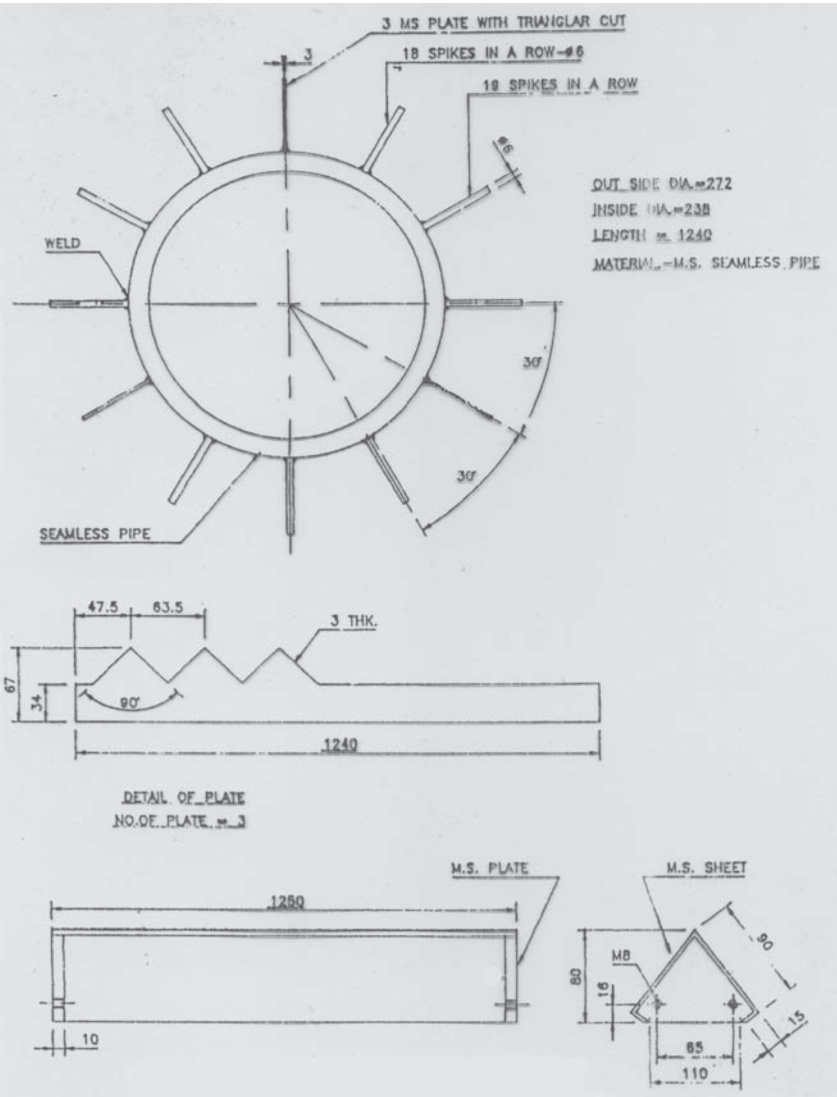
Introduction

Indian cotton is considered to be trashy despite being hand picked and being contaminated by a wide range of impurities gathered during post harvest handling till it reaches the spinning mills. Impurities such as alien fibres, cloth pieces, human hairs, plastics, films, paper bits, metallic objects, oil and grease referred to as contaminants are finding entry into the cotton due to exposure at the farm yard, market yard and ginnery as well as during transport at different stages. Besides this the cotton contains the natural contaminants like leaf bits, boll bracts, stems and other vegetative matter.

The market value of cotton is decided by the quality and purity of its fibres. Thus, for fetching a good price in the market, the baled cotton should contain minimal trash and be free from contamination. The hand picked Indian cotton initially has lower trash content as compared to mechanically harvested cotton in developed countries like USA, Australia and Uzbekistan. Cleanness of cotton can be ensured by the use of appropriate machines before and after ginning. Foreign countries are using a sequence of machines before and after ginning for cleaning mechanically harvested cotton, the machines include rock and green boll trap, cylinder cleaner, stick machine, extractor feeder and lint cleaners. In India, cotton cleaning was not generally practiced even before and after ginning till very recently.

If pre-cleaning is not done, trash particles will adhere to the fibres during the high pressure baling process. Subsequent removal of trash in the blow room at spinning mills becomes difficult, expensive and detrimental to fibre quality. Pre-cleaning is necessary to improve gin stand performance and lint quality. The removal of trash reduces wear and tear of gin parts. Further more opening of clumps of cotton ensures ginning efficiency by presenting cotton to the machine in small uniform units. Cotton pre-cleaning is an essential step for production of quality lint. Use of pre-cleaners in Indian ginning industry is increasing day by day. An effort was made by CIRCOT to develop inclined type cotton pre-cleaner to remove the trash and to improve the lint quality.

Fig. 2 Schematic diagram of spiked cylinder



Materials and Methods

An inclined type cylinder cleaner with six cleaning cylinders was designed and developed at Ginning Training Centre of Central Institute for Research on Cotton Technology (CIRCOT), Nagpur. A horizontal lattice feeder as a feeding attachment was also developed. The developed pre-cleaner was tested on a commercial scale at the ginning factory of M/s. Nagpur District Farmers Co-operative Spinning Mill Ltd., at Nagpur (M.S.) India. Three different varieties; namely, LRA.5166, NHH.44 and H.4, were tested. The cotton of two different grades viz. Super and Fair Average Quality of each variety was taken for the study. The cleaning efficiency, trash percentage and output capacity of pre-cleaner was determined. The cleaned cotton was ginned on Bajaj make double roller (DR) gins in the same factory. The effect of the pre-cleaner on fibre properties was determined. The ginning output from both cleaned and uncleaned cottons were also compared.

Principle of Operation

Cylinder cleaners are used for removing finely divided particles and for opening and preparing the seed cotton for drying and extraction processes before ginning the cotton. The cylinder cleaner consists of a series of spiked cylinders arranged either inclined or horizontal and a lattice feeder. The cotton is fed uniformly along the length of the bottom most spiked cylinder by the lattice feeder. The cylinders are made to rotate at the definite speed in the anticlockwise direction. The rotational motion of the cylinders draw the cotton inside and agitates it across the grid surfaces and conveys the seed cotton across the cleaning surfaces containing small openings or slots underneath of each cylinder. The cleaning surfaces are concave screens. Foreign matter is dislodged from the cotton by the agitating and scrubbing action of the cylinders and it falls through the grids for disposal.

Design and Fabrication

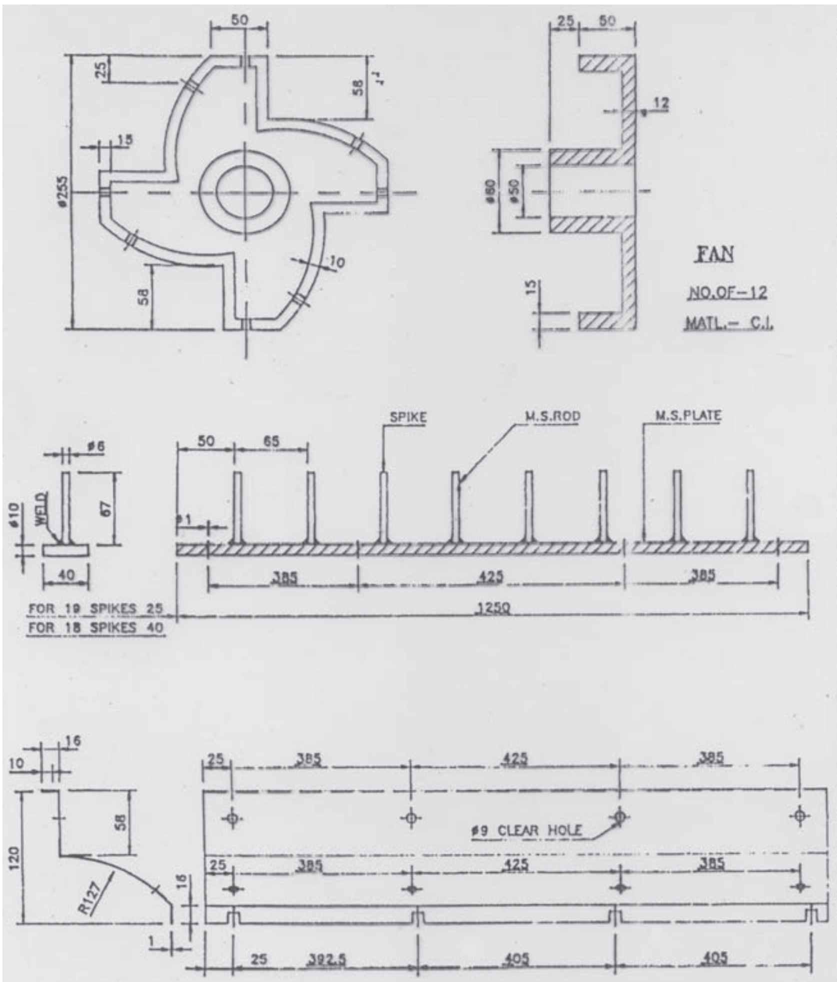
CIRCOT cylinder type inclined pre-cleaner is shown in **Fig. 1**. The main components of the cleaner are the lattice feeder, spiked cylinders, fan type beating cylinders, concave mesh type grid, trash chamber and power drives. In India about 2,000 to 3,000 kg of seed cotton is processed per hour, therefore pre-cleaning capacity is decided accordingly so that one pre-cleaner per factory could be used.

The horizontal lattice feeder consists of an endless belt made up of wooden flats fixed on leather belt. The width of the belt is 1,240 mm. The length of the feeder is 1,750 mm. The endless lattice feeder rotates on four roller shafts provided underneath the belt. The wooden flats of 35 mm in width and 15 mm thick are used. The power to drive the feeder is given by chain and sprocket arrangement from the 2 kW electric motor and reduction gearbox.

The spiked cylinders are made of mild steel seamless pipe. The diameter and length of the cylinder is 272 mm and 1,240 mm, respectively. The cylinder has 9 rows of spikes and three rows of M.S. plate with triangular cuts along the periphery. The angular distance between each row is kept at 30º. The angular distance between the M.S. plates with triangular cuts is kept at 120º. The plate is 3 mm thick and right angle triangle cuts are made on outer edge of the plate. The spikes of 67 mm length and 6 mm diameter are welded on the M.S. flats. The flats with spikes are mounted on the periphery of the cylinder. Every alternate row has 19 and 18 spikes respectively. The schematic diagram of the spiked cylinder is shown in **Fig. 2**. The pre-cleaner has two spiked cylinders; one is located at the inlet side and the other at the outlet side.

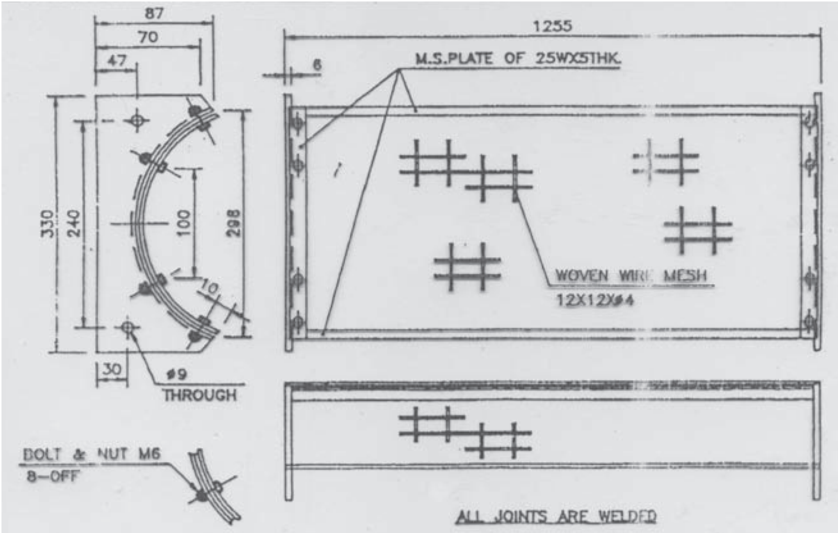
The pre-cleaner has four fan type of beating cylinders. The schematic diagram of the fan type beater is shown in **Fig. 3**. Each fan type

Fig. 3 Schematic diagram of fan type beating cylinder



beater has four blades on which the spikes are fixed similar to that of spiked cylinders. The diameter of the fan type beater is 255 mm. All the four fan beater cylinders are placed in between the two spiked cylinders. The cylinders are mounted on the support frame at an angle of 45º to the horizontal. The power to rotate the cylinders is supplied from the 5 kW electric motor and with the help of belt and pulley arrangement. The cylinders are rotating at a speed of about 400 rpm.

Fig. 4 Sectional view of a woven wire mesh grid



The top surface of the cylinders is covered with the flat metal sheets. Proper gap is maintained between the top cover sheet and tip of the spikes. The concave woven wire mesh grids are provided underneath the cylinders. The grid is made up of 12 x 12 x 4 ø woven wire mesh (**Fig. 4**). All the joints of woven wire mesh are firmly welded. Proper gap is maintained between the grid surface and the tip of the spikes in order to achieve the efficient cleaning of the cotton and to avoid the chocking. The trash chamber is provided below the grid to collect the separated trash. The doors are provided on either side of the chamber for easy disposal of the trash. The detailed specifications of the precleaner are given in **Table 1**. The photograph of the developed precleaner is shown in **Fig. 5**.

Table 1 Specifications of pre-cleaner

Particulars	Diamensions
I. Spiked	
1. Cylinder length	1,240 mm
2. Cylinder diameter	272 mm
3. Rows of spikes on each cylinder	9
4. Total number of spikes on each cylinder	166
5. Rows of MS plates with triangular cuts	3
6. Angular distance between rows of spike	30º
7. Angular distance between two MS plates with triangular cuts	120º
8. Number of spiked cylinder	2
9. Length of spike	67 mm
10. Diameter of spike	6 mm
11. Cylinder speed	400 rpm
II. Fan Beater Cylinder	
1. Cylinder length	1,240 mm
2. Cylinder diameter	255 mm
3. Number of cylinder	4
4. Number of rows of fan blades on each cylinder	4
5. Number of spike son each cylinder	80
6. Cylinder speed	400 rpm
III. Lattice Feeder	
1. Length of feeder	1,750 mm
2. Width of feeder	1,240 mm
3. Width of wooden flat	35 mm
4. Thickness of wooden flat	15 mm
IV. Grid	
1. Woven wire mesh	12 x 12 x 4 ø
V. Power	
1. Power to drive cylinders	5 kW
2. Power to drive lattice feeder	2 kW

Pre-cleaner Testing

The pre-cleaner with horizontal lattice feeder was tested in ginning factory of M/s. Nagpur District Farmers Co-operative Spinning Mill Ltd., Nagpur (M.S.) India. The cotton from eight different lots of three varieties and of two grades was selected for the commercial trials. The cotton varieties were LRA.5166, NHH.44 and H.4. The cotton of Super grade and Fair Average Quality (FAQ) was taken for the study. In Maharashtra, seed cotton is graded in five grades; viz. Super, FAQ, Fair, X and Kawadi. Among these the Super and FAQ grade cotton are considered as the top grade cottons.

The cotton from selected lots were cleaned on the developed pre-cleaner and simultaneously ginned on the double roller (DR) gins. The cotton was fed manually and uniformly on the lattice feeder. The unclean cotton from the same lot was also ginned on the DR gins. The output capacity of the pre-cleaner was determined. The lint output in kg/h after ginning for both the clean and unclean cotton was measured. The lint samples were collected from each trial for measurement of trash content and fibre properties; viz. 2.5 % span length, uniformity ratio, micronaire, strength and colour index. Fibre parameters were tested on M/s Zellwegar Uster (USA). Besides this, the cleaning efficiency of the pre-cleaner, the percentage increase in lint output by ginning cleaned cotton and the percentage increase in ginning percentage by cotton cleaning was also determined.

Results and Discussion

Table 2 shows the pre-cleaner output in kg/h, the cleaning efficiency, percentage increase in lint output by ginning cleaned cotton and percentage increase in ginning percentage by way cotton cleaning. The pre-cleaner output capacity was varied from 2,760 kg/h to 3,156 kg/h for different lots of cotton. The average output capacity of the pre-cleaner was 2,941 kg/h. The trash content in cotton decreased by 0.56 % to 1.17 % by using the developed cylinder pre-cleaner. The average reduction in trash percentage was 0.82 %. The cleaning efficiency was varied between 11.9 % to 26.5 % for different trials. The cleaning efficiency was lowest in the case of LRA.5266 Super grade cotton. This was because of less initial trash content. The overall cleaning efficiency of the pre-cleaner was 20.2 %. Cotton cleaning before ginning resulted in an overall increase of 3.25 % in ginning output and 1 % increase in ginning percentage.

Table 3 depicts the fibre properties of the cleaned and unclean cotton. The marginal improvements in fibre properties were noted with cotton cleaning, which indicates that there is no adverse effect of pre-cleaner on cotton quality. The degree of whiteness was increased considerably.

Conclusions

1. The cylinder type pre-cleaner was designed and developed to suit cleaning of Indian cottons. The overall performance of the cylinder pre-cleaner was satisfactory.
2. The cotton cleaning capacity of the pre-cleaners was found to vary from 2,760 kg/h to 3,156 kg/h with an average output capacity of 2,941 kg seed cotton/h.
3. The cleaning efficiency was found to vary from 11.9 % to 26.5 %. The overall cleaning efficiency of the developed pre-cleaner was 20.2 %.
4. Cotton cleaning before ginning resulted in an overall increase of 3.25 % in ginning output and 1 % increase in ginning percentage.
5. No adverse effect of the pre-cleaner was observed on the fibre

Fig. 5 Photograph of a pre-clener

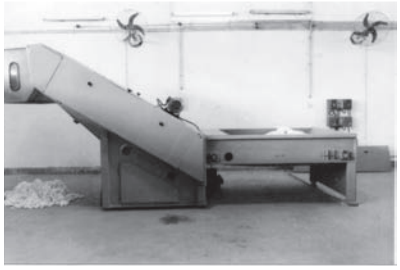


Table 2 Pre-cleaner output, cleaning efficiency and percentage increase in lint output and GP for different cotton varieties by using pre-cleaner

Lot No.	Cultivar	Grade	Process	Output of pre-cleaner, kg/h	Ginning output, kg/h/DR	Increase in lint output, %	Ginning percentage (GP), %	Increase in GP, %	Trash content, %	Reduction in trash content, %	Cleaning efficiency, %
1	LRA.5166	FAQ	WOP	-	59.75	-	35.92	-	4.42	-	-
	LRA.5166	FAQ	WP	2,760	62.50	4.60	36.05	0.36	3.25	1.17	26.5
2	LRA.5166	FAQ	WOP	-	58.29	-	35.83	-	3.92	-	-
	LRA.5166	FAQ	WP	2,850	60.11	3.12	36.08	0.69	3.02	0.90	22.9
3	LRA.5166	Super	WOP	-	63.24	-	36.52	-	3.56	-	-
	LRA.5166	Super	WP	3,156	65.44	3.47	36.89	1.01	3.00	0.56	15.7
4	LRA.5166	Super	WOP	-	62.14	-	35.93	-	3.52	-	-
	LRA.5166	Super	WP	2,912	65.96	6.14	36.09	0.44	3.10	0.42	11.9
5	NHH.44	FAQ	WOP	-	61.11	-	36.05	-	4.18	-	-
	NHH.44	FAQ	WP	3,015	61.95	1.37	36.42	1.02	3.25	0.93	22.2
6	NHH.44	FAQ	WOP	-	60.87	-	35.83	-	4.10	-	-
	NHH.44	FAQ	WP	2,987	62.68	2.97	36.11	0.78	3.23	0.87	21.2
7	H.4	FAQ	WOP	-	60.73	-	35.15	-	3.90	-	-
	H.4	FAQ	WP	2,951	61.67	1.54	35.86	2.02	3.10	0.80	20.5
8	H.4	FAQ	WOP	-	61.39	-	35.23	-	3.89	-	-
	H.4	FAQ	WP	2,895	63.12	2.81	35.83	1.70	3.01	0.88	20.6

WOP: without pre-cleaner, WP: with pre-cleaner, GP: ginning percentage, FAQ: fair average quality properties. The degree of whiteness of lint was improved considerably resulting in grade improvement.

6. One precleaner is suitable for ginning with a 24 Double Roller Gins and its cost is about US$ 4400.

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Table 3 Effect of pre-cleaner on fibre properties

Lot No.	Cultivar	Grade	Process	SL 2.5 %, mm	UR, %	MIC	Tenacity 3.2 mm, g/t	Rd	+b
1	LRA.5166	FAQ	WOP	27.6	48	3.6	23.1	74.6	9.7
	LRA.5166	FAQ	WP	27.5	49	3.8	21.8	77.2	8.5
2	LRA.5166	FAQ	WOP	27.8	47	3.9	21.6	75.1	9.1
	LRA.5166	FAQ	WP	27.7	48	3.8	22.0	75.4	8.9
3	LRA.5166	Super	WOP	28.1	48	3.8	19.0	75.3	9.0
	LRA.5166	Super	WP	27.9	48	3.9	19.5	76.9	8.9
4	LRA.5166	Super	WOP	28.0	48	3.7	20.0	73.6	8.6
	LRA.5166	Super	WP	28.1	49	3.7	20.1	75.3	8.5
5	NHH.44	FAQ	WOP	25.7	47	3.6	23.2	74.5	8.9
	NHH.44	FAQ	WP	25.3	48	3.5	20.6	74.1	8.7
6	NHH.44	FAQ	WOP	26.1	49	3.8	23.1	72.8	9.1
	NHH.44	FAQ	WP	26.0	49	3.6	21.8	74.4	8.9
7	H.4	FAQ	WOP	29.3	47	4.0	22.3	75.6	9.2
	H.4	FAQ	WP	29.2	48	4.0	22.1	76.1	9.1
8	H.4	FAQ	WOP	29.9	48	4.2	22.4	73.3	8.8
	H.4	FAQ	WP	30.0	50	4.1	21.5	74.8	8.7

WOP: without pre-cleaner, WP: with pre-cleaner, SL: span length, UR: uniformity ratio, MIC: micronaire, FAQ: fair average quality, +b: yellowness, Rd reflectance (degree of whiteness)

The Effect of a Fogging System on Sensible and Latent Heat Transfer in a Rose Greenhouse

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Abstract

The objectives of this study were to: evaluate the effects of a fogging system on sensible and latent heat transfer in a rose greenhouse, determine the efficiency of the fogging system, and investigate the cooling and humidifying effects of the fogging system in a plastic greenhouse. Bowen ratio (ß) was also calculated based on the rates of sensible and latent heat transfer. The ß can be used as an indicator of the conditions existing within the plant canopy in the greenhouses. The ß provided a means of estimating components of the energy balance of the plant environment. The experiments were carried out in a multi-span plastic greenhouse 105.6 m wide and 205 m long with 11 spans. The fogging system consisted of: a water softener and filters to prevent nozzle clogging, a water reservoir, pumps and a pressure regulator, and the fog generating nozzles. Three nozzle lines with 82 fog-generating nozzles were installed in each span of the plastic greenhouse. The results showed that the fogging system was able to keep the air temperature inside the PG 6.6 ºC lower than the outside. The air relative humidity inside the plastic greenhouse was increased by 25 % by means of the fogging system examined in this study. The results obtained from this experimental work showed that the greatest efficiency of the FS was 80 %. The rate of sensible heat transfer varied from 6.9 W/m^2 to 476.5 W/m^2, while the rate of the latent heat transfer changed between -87.9 W/m^2 and -825.8 W/m^2 in the plastic greenhouse. The ß ranged from -0.07 to -0.72 during the experimental period. The values of ß indicated that the sensible heat transfer occurred in a direction toward the plant canopy while the latent heat transferred away from it.

Introduction

Various methods for cooling the greenhouse atmosphere may be used to maintain convenient conditions for plant growth. Evaporative cooling (EC) is one of the most efficient methods to maintain convenient climatic conditions into the greenhouse environment. EC is an adiabatic saturation process (no heat gained or lost). Air to be cooled is brought in contact with water at a temperature equal to the wet-bulb temperature (WBT) of the air. The sensible heat of the air is used to evaporate the water, resulting in a decrease of the air's dry-bulb temperature (DBT). Sensible heat is converted to latent heat in the added water vapor. EC is most effective in hot, dry climates, where the wet-bulb depression (WBD) is large and the disadvantage of increased relative humidity (RH) is more than offset by a relatively large temperature drop.

Evaporative cooling systems (ECS) are based on the conversion of sensible heat into latent heat of evaporated water, with the water supplied mechanically. These systems reduce the sensible air temperature and simultaneously increase the humidity by utilizing the heat in the air to evaporate water. The main EC methods used for the greenhouses are classified into two groups: direct evaporative cooling (DEC) and indirect evaporative cooling (IEC). In an IEC system, outdoor air passes along one side of an air-to-air heat exchanger. This air is cooled by

Acknowledgements: I would like to thank NATUREL Agriculture Ltd. for allowing the measurements to be made in the greenhouse.

evaporation by one of the following methods; direct wetting of the heat exchanger surface passing through a wetted pad medium or water spraying into the air stream. The DEC is based on the principle of cooling greenhouse air by the evaporation of water. The evaporation takes energy (about 2,260 kJ/kg_{water}), which is withdrawn from the greenhouse air, which in turn will cool down. The DEC used today are; fan and pad system (FPS), fogging system (FS) and roof cooling system (RCS) (Breuer and Knies, 1995).

Fogging is another system that can be used for direct evaporative cooling of the greenhouses. In recent years, high pressure FS have started to be applied in greenhouses. These FS can be designed and operated to maintain more uniform temperatures and humidity in greenhouses than those that are possible with the FPS. The FS are more expensive than the FPS, but when uniform temperatures and humidity level are important they can be the best method of the EC. A system applying the same principle, as FPS is the FS. The FS is based on spraying the water in small droplets (in the fog range 2-60 µm in diameter) in order to increase the water surface in contact with the air (Arbel et al, 2000). Water is forced through the nozzles placed above the crop in a greenhouse producing a fog. The free-fall velocity of the droplets is slow and the air stream inside the greenhouse easily carries the droplets. Fog droplets can be generated by several methods. Droplets less than 30 µm in diameter are created using high-pressure pumps and nozzles or spinning atomizers.

Rose production has considerable importance among the greenhouse products. Greenhouse rose production under hot and sunny conditions often requires some climatic protection to prevent plant overheating and to produce marketable crops. Rose flowers produced in naturally ventilated greenhouses during the summer are of poor quality, presumably because of high temperatures and may have low air humidity. If the high external air temperature is associated with low absolute humidity, the EC can provide an effective way to reduce the thermal and water stresses on greenhouse plants (Dayan et al, 2000). Of the processes affecting plant production, flowering and fruit-set may be the most sensitive to high temperatures. Concerning rose plants response to the EC, Plaut et al (1979) observed a significant improvement of flower quality under evaporative cooling conditions.

A medium VR is usually determined from a sensible heat balance analysis. The maximum VR can be computed taking into account removable of the available sensible heat. In some areas, where summer ventilation is coupled with the EC, RH of the air is important. Moisture content (absolute humidity) of the air during the summer is generally used as one of the factors to calculate ventilation requirements. Since the type of the ECS used does not significantly affect the total heat transfer, the ratio of the sensible to latent heat will change with the type of ECS used. The objectives of this study were to: evaluate the effects of a fogging system on sensible and latent heat transfer in a rose greenhouse; determine the efficiency of the FS for the greenhouses; and investigate the cooling and humidifying effects of the FG in plastic greenhouse (PG). For this purpose, climatic measurements from a large commercial greenhouse equipped with the FS were collected, presented and discussed. The efficiency of the FS was calculated based on the dry-bulb temperature inside and outside the greenhouse and the wet-bulb temperature outside the greenhouse. Cooling and humidifying effects of the FS in the PG were discussed. In addition, the rates of sensible and latent heat transfer and the values of Bowen ratio were also calculated in the PG equipped with the fogging system.

Literature Review

Comprehensive studies have been carried out concerning the efficiency and modeling the ECS by many researchers. Giacomelli (1993) tested various cooling systems to compare cooling potentials and to get maximum uniformity throughout the greenhouse. The efficiency of the EC ranged from 40 % to 70 %, and the minimum gradients of temperature were obtained with high ventilation rates and water flow rates. Willits (2000) examined the limitations and constraints facing greenhouse-cooling designers as described by models of complexity. Kittas et al (2001) investigated temperature and humidity gradients during summer in a commercial greenhouse producing cut roses, equipped with a ventilated cooling-pad system and a half-shaded plastic roof. In a steady regime, the cooling process reached 80 % efficiency and succeeded in maintaining greenhouse temperatures that were cooler (up to 10 ºC lower) than outside. Cladding materials used in the greenhouse may influence the efficiency of the EC. Al-Amri (2000) investigated the efficiency of the FPS in two experimental greenhouses: the greenhouse covered by 0.8 mm thick corrugated fiberglass reinforced plastic panels and the greenhouse covered by 0.1 mm thick double layers of polyethylene (PE) sheets. It was found that the average efficiency of the ECS for the two greenhouses was 59.32 % and 46.19 %, respectively. Thus, the fiberglass cover compared with the PE mainly increased the efficiency of the cooling process by 28.43 %. Abdellatif (1993) found that the greatest values of cooling effect (13.2 ºC) and cooling efficiency (81.5 %) were achieved with the greatest value of the WBD (16.2 ºC) and the lowest value of the air RH (26 %) and vice versa.

Seginer (1994) found that artificial EC is mainly effective when crop transpiration is low, and Fuchs (1993) reported that a highly transpiring crop combined with a proper VR is the most effective mechanism to keep leaf temperatures moderate (Kittas et al, 2001). Previous work on the ECS, mainly the FS, applied to greenhouses considered thermodynamic system efficiency and environmental effects. Giacomelli et al. (1985) investigated the effects of the ECS on the greenhouse microclimate. Montero et al (1990) carried out a research on cooling of greenhouses with compressed air fogging nozzles. A theoretical study was conducted by Arbel et al (2000) to evaluate an ECS for greenhouses by installing uniformly distributed the Fog Generating Nozzles (FGN) in the space over the plants.

FS may lead to greenhouse air temperatures lower than the outside air temperature and its efficiency increases with the decrease of ambient humidity, but it is effective also in humid coastal environments (Montero and Segal, 1993). More recent works have focused on the effect of the FS on crop transpiration. The effect of the FS on transpiration and vapor pressure deficit was examined by Boulard et al (1991) in tomato cultivation and Baille et al (1994) in rose cultivation. It was found that use of the FS strongly affected the diurnal course of the transpiration and vapor pressure deficit. Kittas et al (2000) investigated the effect of a FS on canopy transpiration and water vapor conductance. Arbel et al (1999) recommended that future studies should focus on examining the system set-up for large units and a combination of the FS with natural ventilation. The simplest model of the cooling process is one based on the steady-state energy balance. Seginer and Livne (1978) developed a model based on differential sensible and latent heat balances conducted along a slice of greenhouse of unit width and length.

There is very little information on the coupling between the heat and mass exchanges of plants and the ventilation air. The heat removed from a greenhouse with the ventilation air consists of sensible heat and latent heat losses. The sensible heat is that portion of the total energy removed from the greenhouse in the ventilation air by a temperature increase in the air. The latent heat is the heat removed by vaporized water. The EC uses heat from the air to vaporize water and thus decreases the air temperature. This increases the RH of the air and will be more effective if the initial RH is low. RH will generally be lowest during the hottest part of the day and some benefit can be gained by the EC. A lower ventilation rate (VR) can be used when the EC is applied. The evaporation of the water in the greenhouse will reduce the sensible heat content of the air and increase the latent heat (moisture) content of the air.

Materials

Plastic Greenhouse

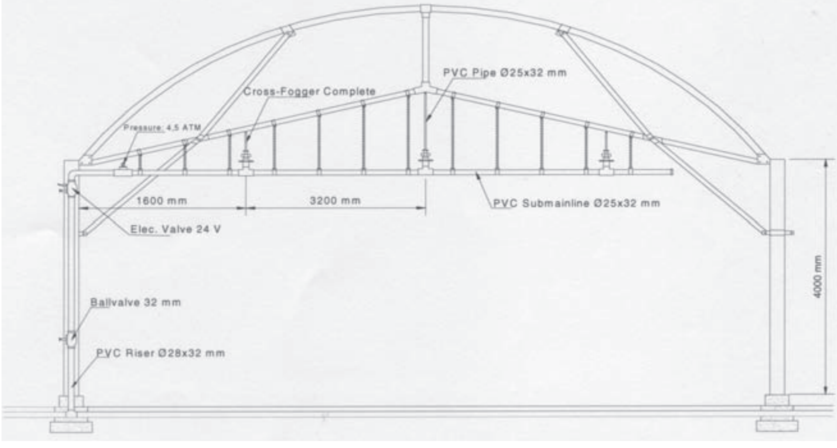
The experiment was carried out from 16 May to 12 June, 2002 in a large commercial greenhouse located in the Çukurova Region (Yenice-Adana). The multi-span PG, 105.6 m wide and 205 m long, was made of 11 spans. Each span was 9.6 m wide by 205 m long, with a ridge at 5.6 m and a gutter at 4 m above soil surface (**Fig. 1**). The cladding material was 150 µm PE film, with terrestrial infrared and UV absorbing additives.

The PG had continuous roof ventilation at the ridge and was oriented in an East-West direction. For the experimental period, meteorological parameters in the PG were measured when the roof-opening angle was the maximum. Each span of the PG included a computer-controlled FS. The PG has been used commercially for cut rose production. The rose plants have been cultivated in 0.56 (width) x 1.04 (length) x 0.23 (depth) m containers filled with volcanic scoria and organic materials. The containers were laid parallel to the nozzle lines nine 200 m rows, in each span, 1.82 m between row centers. Water and plant nutrients (N, P, K and micro-elements) have been applied with an automatic drip irrigation system.

Fogging System

The FS consists of: a water softener and filters to prevent nozzle clogging, a water reservoir, pumps and a pressure regulator, and the FGN. The FGN were distributed uniformly over the PG. Main elements of the FS used in the PG are given in **Fig. 1**. Three nozzle lines with

Fig. 1 Plastic greenhouse equipped with the fogging system



82 FGN were installed in each span of the PG. Required pressure for the FGN was 4.5 Atm. At the each nozzle line, 82 FGN were uniformly located with 2.5 m nozzle spacing. A central water feed system was electrically operated depending on the RH value inside the PG.

Meteorological Measurements

A measuring system, including psychometric units for measuring the WBT and DBT, was installed in order to control the operation of the FS. The WBT and DBT were measured on top of the canopy at 1.5 m inside the each span of the PG. Solar radiation was measured by Li-Cor Silicium probes. The velocity and direction of the wind were also recorded with vector instruments. The analogue signals from the sensors were sampled at 30 s intervals, averaged every 30 minutes, and stored in a network of data loggers connected to the sensors.

Methods

Sensible Heat Transfer

The efficiency of EC is a common term used to indicate saturation efficiency. This is the ratio of change in saturation achieved to potential change in saturation. The ECS are normally evaluated in terms of an EC or saturation efficiency, which is defined as the ratio of temperature drop provided by the ECS to the difference between DBT and WBT. The WBT is important in the ECS. It is the WBT, not the RH, that determines the temperature that air can be cooled by the evaporation of water. The efficiency of the FS was determined by the following definition (Al-Amri, 2000; Kittas et al, 2001):

$$FSE = \frac{DBT_o - DBT_g}{DBT_o - WBT_o} \times 100 \quad .....(1)$$

where FSE is fogging system efficiency (%), DBT_o is the dry-bulb temperature outside the greenhouse (ºC), DBT_g is the dry-bulb temperature inside the greenhouse (ºC) and WBT_o is the wet-bulb temperature outside the greenhouse (ºC).

Air Flow Rate

Based on the assumptions of a steady-state condition and that the desired temperature and the RH in the greenhouse are known, the required air mass flow rate can be approximated by equation 2 below (Arbel et al, 1999).

$$VR = \frac{I\tau\alpha - U(T_g - T_o)}{h_g - h_o}$$

for $h_g > h_o$, ...(2)

where AFR is air (ventilation) flow rate (kg/s m^2), I is solar radiation (W/m^2), τ is the radiation transmission of the greenhouse, α is the proportion of the solar radiation entering the greenhouse that is used to increased the internal air enthalpy, U is the overall heat loss coefficient of the greenhouse (W/m^2 ºC^1), T_g is the air temperature inside the greenhouse (ºC), T_o is the air temperature outside the greenhouse (ºC), h_g is the air enthalpy inside the greenhouse (J/kg$^1_{\text{dry air}}$) and ho is the air enthalpy outside the greenhouse (J/kg$^1_{\text{dry air}}$).

The value of α depends on the proportion of the floor, which is covered by plants, and generally lies in the range of 0.3-0.7. In this study, the values of 0.5 and 0.75 were used as α and τ, respectively. The value of U for single cover plastic greenhouses varies in the range of 6.0-8.0 W/m^2 ºC. In this study, a U value of 7.0 W/m^2 ºC was used to determine the VR in the PG.

Sensible Heat Transfer

Sensible heat is the heat which results in a temperature change only when there is a transfer. The transfer of heat by sensible means depends on the material properties and the conditions of the ambient environment (i.e., DBT, air movement, surrounding surface temperatures, etc). The nature of various effects on the SHT within the greenhouses is important. From the laws of heat transfer, transfer of sensible heat within the plant environment occur according to heat transferred in response to a gradient of temperature. The SHT in the greenhouse is realized due to the Air Temperature Difference (ATD) between the outside and inside the PG. The total quantity of sensible heat transferred is related to the density of the air being moved and the specific heat of the air. The rate of the SHT in the PG was calculated by using the following equation:

$$Q_s = [(VR/A_g)\rho c_{pa}(T_o - T_i)], \quad ....(3)$$

where Qs is the rate of the SHT (W/m^2), VR is the ventilation rate (m^3/s), Ag is ground surface area of the PG (m^2), ρ is the density of air (kg/m^3), c_{pa} is the specific heat of air (J/kg ºC), T_o is air temperature outside the PG (ºC), and T_i is air temperature inside the PG (ºC).

Latent Heat Transfer

Latent heat is that heat which causes a change in state, but no change in temperature. In the context of the greenhouse the most important processes involving latent heat are transpiration, in which water evaporates from leaves, the evaporation of water from the soil and the condensation of water on the inner surface of the greenhouse cover. Condensation can only occur if the saturated absolute humidity at the temperature of the cover is lower than the absolute humidity of the greenhouse air. In an ECS it is latent heat of vaporization that is absorbed by the water as it changes to a vapor. The amount of latent heat required for vaporization of water decreases with an increase in temperature. The latent heat to be removed from the greenhouses will change the following factors: water wastage, temperature, VR, relative humidity, and air velocity over the plant canopy. Energy transferred in the form of the latent heat depends on the latent heat of vaporization and the density of the air. The rate of the LHT was calculated based on the Absolute Humidity Difference (AHD) between the inside and outside air in the PG by the following equation.

$Q_1 = [(VR/A_g)\rho h_{fg}(w_o\text{-}w_i)]$, ...(4)

where Q_1 is the rate of the LHT (W/m^2), hfg is latent heat of vaporization (J/kg), wo is the absolute humidity of the air outside the PG (kg/kg $_{dry\ air}$), and wi is the absolute humidity of the air inside the PG (kg/kg $_{dry\ air}$).

Bowen Ratio

The ECS are evaluated based on the relationship between the SHT and the LHT in the greenhouse. The ratio of the SHT to the LHT has been termed Bowen ratio (() and is defined as:

$$ß = \frac{\text{Sensible Heat Transfer}}{\text{Latent Heat Transfer}} = \frac{SHT}{LHT}, \quad ....(5)$$

where ß is a dimensionless number termed the Bowen ratio. The ß can be used as an indicator of the conditions existing within the plant canopy in the greenhouses. The ß provides a means of estimating components of the energy balance of the plant environment. The transfer of energy horizontally can affect the magnitude and sign of the ß. If the surface of the plant canopy is wet, evaporation takes place and the AHD between the inside and outside air will be large. Thus, most of the energy being carried away from the plant canopy will be transferred in the form of the latent heat. Under these conditions the value of the ß will be a small positive number. If the plant canopy is dry, then the AHD between the inside and outside air will be small. In this case, the actual value of the ß will be large, indicating that most of the energy is being transported as a sensible heat flux.

Results and Discussion

The experiment was carried out in the PG from 16 May to 12 June 2002. The air temperatures inside the PG were compared to the outside air temperatures as one important measure of the FS. From all the recorded climatic values, the results of the three consecutive days when the outside air temperatures were highest were discussed in this paper.

Cooling and Humidifying Effects of the Fogging System

Fig. 2 and **Table 1** summarize the outside and inside air temperatures and air RH during the experimental period. The air temperature inside the PG changed between 23.1 ºC and 34.3 ºC, whereas the outside air temperature in the range of 23.7-40.4 ºC. The air temperature inside the PG, which was only 23.1 º C at 10:00 reached to the maximum value (34.3 ºC) at 13:30 in the afternoon. Both of the air temperatures inside and outside the PG were generally stable during the morning and afternoon. It was found that the average daily value (ADV) of the inside and the outside air temperatures were 31.6 ºC and 35.4 º C, respectively. While the air temperature difference (ATD) between inside and outside the PG was only 0.63 ºC at 07:00 in the morning, the ATD reached to 6.6 ºC at 16:00 in the afternoon. The average ATD between the outside and inside the PG was 3.84 ºC for the period of time as covered by **Fig. 2**. The ATD between the outside and inside the PG was lower in the morning since the efficiency of the FS was lower. The ATD between outside and inside the PG increased as the efficiency of the FS increased during the afternoon. In other words, the air temperature inside the PG decreased as the efficiency of the FS increased during the afternoon. The air temperature inside the PG decreased as the sensible and latent heat transfer from the PG to the outside increased. The maximum ATD between the control and inside the PG was 10.6 º C during the experimental period. **Fig. 2** clearly shows that substantial decrease of ambient air temperature inside the PG occurred when the air temperature outside the PG exceeded 40 ºC. Under these conditions, the FS provided a cooling effect (ATD between the outside and inside the PG) of 6.6 ºC. The results showed that the FS was able to keep the air temperature inside the PG 6.6 ºC lower than the outside. This

Fig. 2 The change of the air temperature and air RH as a function of time

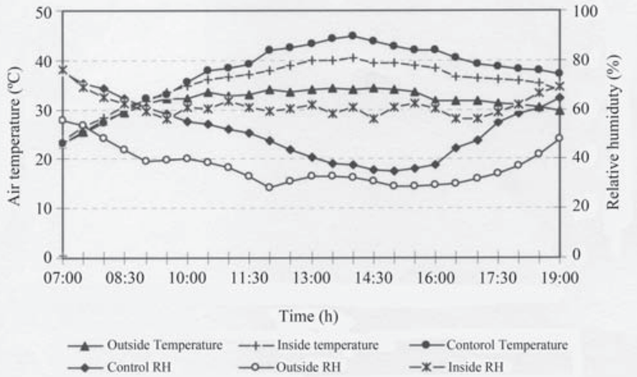
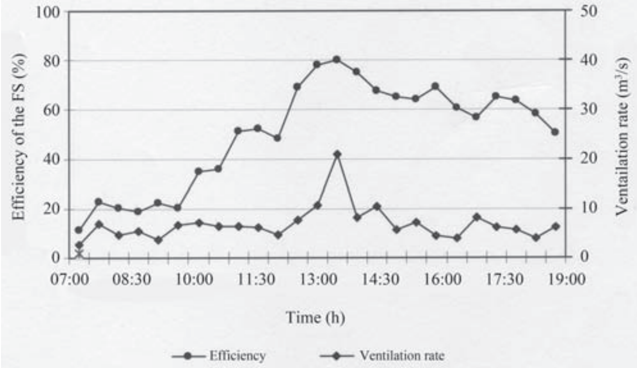


Fig. 3 The change of the efficiency of the fogging system as a function of time



good performance was due to the high efficiency of the FS, which was calculated by using the Eq. 1. In this experiment the cooling effect of the FS was lower in comparison with the results obtained by Abdellatif (1993) (13.2 ºC) and Kittas et al (2001) (up to 10 ºC). The FS did not substantially reduce the average air temperature around the rose plants in the PG. This result is due to the fact that the WBT depression at Adana is normally low, so that the potential cooling effect of the FS is therefore limited. The evaporation in the PG increases the RH of the incoming air and of the PG.

The air RH inside the PG ranged from 56.3 % to 76.3 %, whereas the air RH outside the PG was in the range of 28.1-55.7 %. The air RH inside the PG dropped from 76.3 % (at 07:00 in the morning) to 56.3 % at 14:30 in the afternoon. During the experimental period, the ADV of the inside and the outside RH were 61.7 % and 37.1 %, respectively. The air Relative Humidity Difference (RHD) between inside and outside the PG was only 15.4 % at 07:30 in the morning, the RHD reached to 33.3 % at 15:30 in the afternoon. The average RHD between the inside and outside the PG was 24.6 % for the period of time covered by **Fig. 2**. This means that the air RH inside the PG was increased by approximately 25 % by means of the FS examined in this study. Similarly the ATD, the RHD between the inside and outside the PG increased with increasing the efficiency of the FS during the afternoon. In other words, the air RH inside the PG increased with increasing the efficiency of the FS during the afternoon. The RHD between the inside and outside the PG reached to 33.3 % when the ATD between the inside and outside the PG was 5.33 ºC at 15:30 in the afternoon. The FS provided a humidifying effect (RHD between the inside and the outside) of 33.3 %. The results showed that the FS was able to keep the air RH inside the PG 33.3 % higher than the outside. The average RHD between the control and inside the PG was 10.1 % during the experimental period. It was found that the efficiency of the FS was directly related to the outside air temperature, air RH and saturation pressure of the air.

Efficiency of the Fogging System

Fig. 3 shows the variation of the efficiency of the FS as a function of time. The efficiency of the FS varied as a function of time of the days in which the experiment was carried out. The efficiency of the FS was strongly affected by the difference between the DBT and WBT of the outside air that was affected mainly by air RH. The difference between the DBT and WBT is referred to as the WBD. The efficiency of the FS increased as the air RH outside the PG decreased. Therefore, the FS' s effect as an ECS is greater with lower the outside air RH. This is in agreement with Arbel et al (1999). The efficiency of the FS ranged from 11.7 % to 80 % during the experimental period. It was found that the average daily efficiency of the FS was 50.5 %. Al-Amri (2000) found that the average efficiency of the ECS was 46.19 % in the experimental greenhouse covered by 0.1 mm thick double layers of the PE sheets. The present FS was more effective in comparison with the results obtained by Arbel et al (1999) and Al-Amri (2000). Arbel et al (1999) compared the FS and the FPS under similar condition. According to the their results, the efficiency of the FS is better than that of the FPS with respect to uniform distribution of temperature and humidity in the greenhouse. An efficiency of 75 % was obtained for the FPS in their experiments. Giacomelli (1993) found that the efficiency of the EC of various cooling systems ranged from 40 % to 70 %. Since the WBD was the greatest at 13:30 in the afternoon when the DBT was normally at its peak, the greatest efficiency of the FS (80 %) was achieved at this time. The greatest efficiency of the FS (80 %) was achieved at 33 % outside air RH. This is in agreement with results obtained by Abdellatif (1993) and Kittas et al (2001). As mentioned before, Abdellatif (1993) and Kittas et al (2001) found that the cooling efficiencies were 81.5 % and 80 %, respectively. Albright (1989) also reported that a well-designed ECS might have an operating efficiency of up to 80 %. If the outside temperature and the air RH are known, the WBT, that would be the temperature of the entering air, can be calculated. For example, if air at 35 ºC and 20 % RH has a WBT of 18.8 ºC, the difference between 35 ºC and 18.8 ºC is the WBD (16.2 ºC). The greatest value of evaporative cooling efficiency of the FS was 80 % in this experiment. This means that the FS would cool the air by 0.80 (16.2 ºC) = 13 ºC.

The change of the VR in the PG is also given in **Fig. 3** for the experimental period. The VR is influenced by environmental factors such as wind speed, wind direction and the ATD between the inside and outside the greenhouse. The required VR increased as the air temperature outside the PG rose. Similar results were obtained by Arbel et al.

Table 1 The values of the temperature and air RH inside and outside the PG

Climate parameters		Values		
		Minimum	Maximum	Average
Outside	Air temperature (ºC)	23.7	40.4	35.4
	Air RH (%)	28.6	55.7	37.1
Inside	Air temperature (ºC)	23.1	34.3	31.6
	Air RH (%)	56.1	76.3	61.7
Control	Air temperature (ºC)	23.1	44.9	37.6
	Air RH (%)	34.9	75.1	51.6

(1999). The wind speed outside the PG was in the range of 0.6-4.1 m/s. The main value of the wind speed was 2 m/s during the experimental period. The VR was only 5.46 m^3/s at 07:00 in the morning. One factor that indirectly influences the VR is the solar radiation since it is an important component of the energy balance in greenhouses. Since the air temperature and solar radiation increased outside the PG, the VR reached 41.56 m^3/s at 13:30 in the afternoon. It was found that the highest VR (41.56 m^3/s) occurred when the wind speed was 1.5 m/s at 13:30 in the afternoon, since the ATD between the outside and inside the PG was 5.7 ºC. In this case, the ATD had a strong influence on VR when the wind speed was lower. This result is in agreement with Babtista et al (1999) who investigated the influences of the wind speed, wind direction and temperature difference on the VR in a four span glasshouse. They found that temperature difference affected the ventilation rates under low wind speed. The VR dropped from 41.56 m^3/s to 12.28 m^3/s at 19:00 in the evening. The average VR of the PG was 13.64 m^3/s for the period of time covered by **Fig. 3**. This means that 13.64 m^3 of warm and moist air per second was removed from inside the PG to the outside. The lower air exchange probably caused the lower transpiration rates under the FS in the PG. As it shown in **Fig. 3**, the efficiency of the FS increased to a maximum value (80 %) when the VR was 41.56 m^3/s at 13:30 in the afternoon.

Fig. 4 represents the relationship between the FSE and AHD (w_i-w_o) and shows that the coefficient of the determination (R^2) is 0.80. A linear regression of the plotted points was used to find the relationship between the FSE and AHD. As indicated by **Fig. 4**, the FSE increased as the AHD between the inside and outside air rose. The efficiency of the FS (%) as a function of absolute humidity difference (g/g $_{dry\ air}$) in 2002 at Adana was:

$$FSE = 8.889 + 9.0915\ (w_i - w_o) \quad .....(6)$$

The Rate of Sensible and Latent Heat Transfer

Figs. 5 and **6** show the rates of the SHT and the LHT were calculated by using Eqs. 3 and 4, respectively. The rates of the SHT and the LHT in the PG are also given in **Table 2**. The rate of SHT in the PG changed between 7 W/m^2 and 476.5 W/m^2 for the period of time covered by **Fig. 5**. The rate of the SHT in the PG increased as the ATD between the outside and inside in the PG rose. As shown in **Fig. 5**, the rate of the SHT increased from 07.00 in the morning to 13:30 in the afternoon during the experimental period. While the rate of SHT was only 7 W/m^2 at 07:00 in the morning, it increased to 476.5 W/m^2 at 13:30 in the afternoon. The average rate of the SHT was only 47.8 W/m^2 in the morning (in the period of 07:00-12:00) due to lower ATD. As can be expected, the average ATD between the outside and inside the PG was only 2 ºC in this period. Since the average ATD increased 5.19 ºC in the afternoon (in the period of 14:00-19:00), the average rate of the SHT increased more than twofold (133.3 W/m^2) in this period. It was found that the average daily rate of the SHT was 115.35 W/m^2 during the experimental period. On the other hand, the rate of the SHT in the PG was also affected by the AHD between the inside and outside air. The AHD between the inside and outside air was only 0.73 g/g $_{dry\ air}$ at 07:00 in the morning. This means that the surface of the plant canopy inside the PG was dry in the morning. In this case, most of the energy in the PG was transported as a sensible heat flux. Boulard et al (1997) estimated that between 55 an 80 % of the total sensible heat transfer was created by the mean flow and less than 45 % by the turbulent component.

The rate of the LHT in the PG ranged from of -87.9 W/m^2 to -825.8 W/m^2 for the period of time covered by **Fig. 6**. The average daily rate of the LHT was -326.2 W/m^2 during the experimental period. The rate of the LHT in the PG was strongly affected by the AHD between the inside and outside air, which was affected mainly by the air RH. The rate of the LHT in the PG

Fig. 4 The relationship between the efficiency of the fogging system and the absolute humidity difference

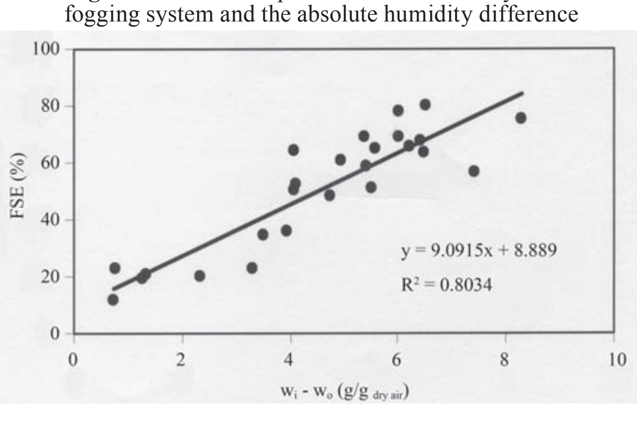


Table 2 The rates of the sensible and latent heat in the plastic greenhouse

Parameters	Values		
	Minimum	Maximum	Average
Sensible heat transfer (SHT, W/m^2)	7.0	476.5	115.35
Latent heat transfer (LHT, W/m^2)	-87.9	-825.8	-326.2
Bowen ratio (ß)	-0.078	-0.719	-0.329
Air temperature difference (ATD, ºC)	0.63	6.60	3.84
Absolute humidity difference (ATD, g/g $_{dry\ air}$)	0.73	8.28	4.58

increased as the AHD increased. Similarly the rate of the SHT, the average rate of the LHT was -263 W/m^2 in the morning (in the period of 07:00-12:00) since the average AHD was only 2.86 g/g $_{dry\ air}$. The average AHD increased 5.91 g/g $_{dry\ air}$ in the afternoon (in the period of 14:00-19:00), thus the average rate of the LHT increased (307.1 W/m^2 in this period. The AHD between the inside and outside air reached 8.28 g/g $_{dry\ air}$ 14:00 in the afternoon. This means that the surface of the plant canopy in the PG was wet in the afternoon. Thus, the evaporation rate was high in the PG. In this case, most of the energy being carried away from the plant canopy was transferred in the form of the latent heat. Bailey et al (1993) found that a well irrigated and fully developed crop may convert nearly 70 % of the sensible heat into the latent heat. As it can be seen in **Figs. 5** and **6**, the rates of the SHT (476.5 W/m^2) and the LHT (-825.8 W/m^2) were the highest at 13:30 in the afternoon when the efficiency of the FG reached 80 %.

Due to the plant morphology the plant canopy absorbed most of the energy entering the PG as solar radiation. The plants in the PG equipped with the FS dissipated a large percentage of this energy as the latent heat. During the afternoon transpiration exceeded net radiation and lowered air temperature inside the PG. By lowering the high transpiration normally obtained with natural ventilation, the shading and FS partially lost the effectiveness of their heat load reduction. Wang et al (2000) reported that the sensible and latent heat transfer between vegetation and interior air are largely dependent on the value of crop aerodynamic resistance.

Bowen Ratio

The values of ß were calculated by using the Eq. 5. The change of the values of ß and the AHD is shown in **Fig. 7** as a function of time. The values of ß and the AHD between the inside and outside air are given in **Table 2**. As shown in **Fig. 7** and **Table 2**, the AHD between the inside and outside air was in the range of 0.73-8.28 g/g $_{dry\ air}$ during the experimental period. The ADV of the AHD between the inside and outside air was 4.58 g/g $_{dry\ air}$ for the experimental period.

The ß changed between -0.07 and -0.72 for the period of time covered by **Fig. 7**. The ADV of ß was -0.329 during the experimental period. As shown in **Fig. 7**, the ß increased as the AHD between the inside and outside air increased. In the morning (in the period of 07:00-12:00), the ß (-0.162) was higher compared with the values (-0.462) in the afternoon (in the period of 14:00-19:00). This means that the average rate of the SHT in the morning was lower than that of the afternoon since the ATD between the outside and inside the PG was lower in the morning. When the ß taken into account, the rate of the LHT was higher than the rate of the SHT in the PG, due to the EC effect of the FS used in the PG. A negative value of the ß indicate that the air temperature is lower inside the PG than that of the outside while the air absolute humidity is greater inside the PG than that of the outside air. Under these conditions the SHT occurred in a direction toward the plant canopy while the latent heat transferred away from it.

The relationship between the ß and the ATD is given in **Fig. 8**. The linear regression coefficient of determination (R^2) was about 60 %. The ß increased as the ATD between the outside and inside air rose. The ß as a function of the air temperature difference (ºC) in 2002 at Adana was:

$$ß = -0.572 - 0.0708\ \Delta T. \ldots\ldots\ldots\ldots(7)$$

Conclusion

It is necessary to know the ventilation characteristics of a greenhouse in order to provide good control of the inside environmental conditions, and good crop yield of high-quality produce. The importance of air temperature and the RH are demonstrated by the many different effects it has on the growth

Fig. 5 The rate of the sensible heat transfer in the plastic greenhouse as function of time

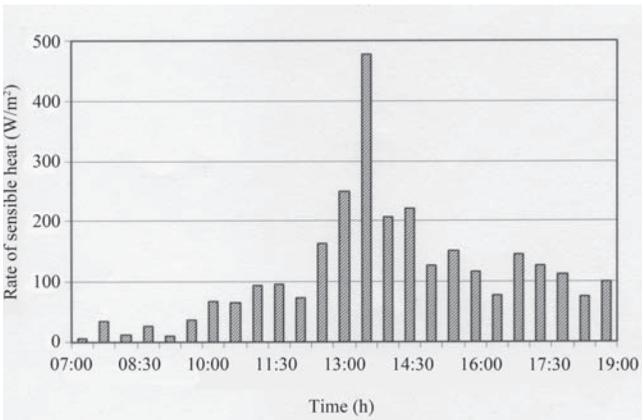
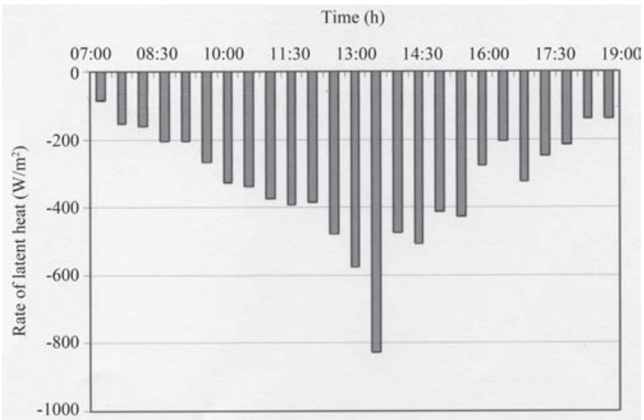


Fig. 6 The rate of the latent heat transfer in the plastic greenhouse as function of time



and development of protected cropping. Environmental factors particularly air temperature and RH influence the rates of photosynthesis, respiration, and other metabolic process. Uniform conditions of temperature and RH in the PG were observed with the FS. The FS was able to keep the air temperature inside the PG 6.6 ºC lower than the outside. On the other hand, the air RH inside the PG was increased by 25 % as average by means of the FS examined in this study. It was found that the average efficiency of the FS was 50.5 %. The efficiency of the FS increased linearly with the EFR and AHD between the inside and outside air. The efficiency of the FS increased when the outside air RH was lower. The VR in this experiment was affected mainly the temperature difference. However, greenhouses must be equipped with side and ridge ventilators in order to increase the air change due to the wind and the temperature difference.

There is very little information on the coupling between the heat and mass exchanges of plants and the ventilation air. The evaporation of the water in the greenhouse by the FS reduced the sensible heat content of the air and increased the latent heat content of the air. The rate of the SHT changes based on the ATD between the inside and outside in the PG, while the rate of the LHT changes based on the AHD between the inside and outside air. The FG used in the PG removed the latent heat by vaporized water. The ß can be used as an indicator of the conditions existing within the crop canopy in the greenhouses. The ß provides a means of estimating components of the energy balance of the plant environment. The values of the ß that were determined in this experimental work, indicate that the SHT occurred in a direction toward the plant canopy while the latent heat transferred away from it. The rates of the SHT and LHT should be considered along with the reduced cost of the FS used in the greenhouse.

The results obtained from this experimental work show that the changes in inside air RH took place throughout the day just as air temperatures varied. Usually, the period of the lowest air RH was realized during the hottest time of the day, when the greatest degree of cooling was required. Fortunately, the FS at that time was more efficient. The air inside the PG was continually cooled by evaporative process to approximately 3.84 ºC over the DBT. For that reason, the ECS should use in the greenhouses during the hottest period in summer. The FS could be operated at various pressures until the conditions in the greenhouse were stabilized. Thus, the adjustment of the pressure may provide the desired conditions of temperature and RH in the greenhouse. For installation and operation of the FS in the greenhouses built as large units, the FGN should uniformly distributed in the space above the plant canopy, and the openings in the roof should be uniform. Future studies should focus on: modeling the efficiency of the FS and utilization of the FS with the natural ventilation in the greenhouses. Such experimental studies will be very useful to optimize the management of the FS in hot and dry climates.

Nomenclature

A: ground surface area (m^2)

c_p: specific heat of air ($J\ kg^{-1}\ ºC^{-1}$)

DBT: dry-bulb temperature (ºC)

FSE: fogging system efficiency (%)

h_{fg}: latent heat of vaporization ($J\ kg^{-1}$)

LHT: latent heat transfer

Q: heat transfer rate (Wm^{-2})

SHT: sensible heat transfer

T: air temperature (ºC)

VR: ventilation rate (m^3s^{-1})

WBT: wet-bulb temperature (ºC)

w: the absolute humidity of the air ($kg\ kg^{-1}_{dry\ air}$)

Greek letters

ß: Bowen ratio

Fig. 7 The change of bowen ratio and the absolute humidity difference as a function of time

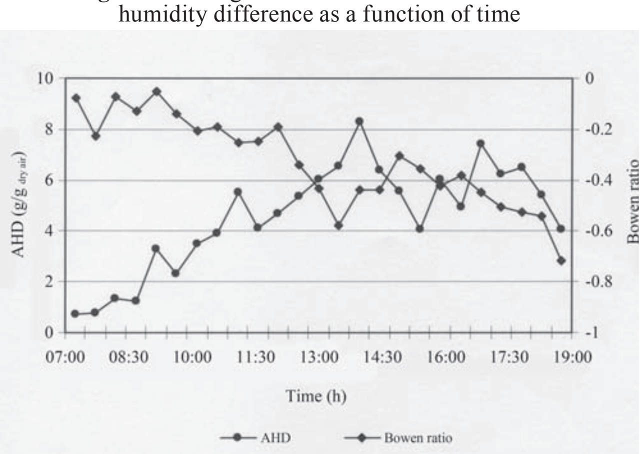
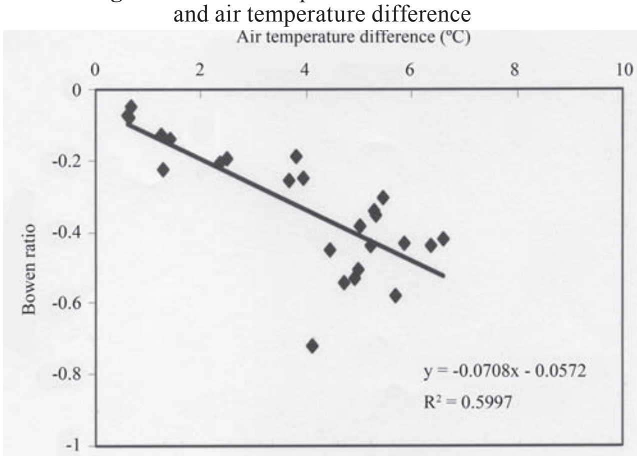


Fig. 8 The relationship between the bowen ratio and air temperature difference



ρ: air density (kg/m^3)

Subscripts

g: greenhouse

i: inside

l: latent

o: outside

s: sensible

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Evaluation of Wheat Bed Planting System in Irrigated Vertisols of Sudan

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Abstract

Wheat is a strategic crop in Sudan. It is produced exclusively under irrigation during the short winter season between November and March. Bed planting is proven in many parts of the world to reduce the cost of production and irrigation water. A field experiment was conducted for two seasons (2001 and 2002) with modification of an old planter to perform ridging and sowing in one operation. The bed planting treatment was compared with the recommended seed drill on flat and with the traditional manual broadcasting plus ridging to 80 cm. In the second season the hoe furrow openers of the bed planter were replaced by disc type and more seed rates were tested. Water use was monitored for the two seasons. Results showed that bed planting resulted in significantly lower yields compared to the other treatments in the first season. In the second season there were no significant differences in grain yields for all the treatments. However, lower seed rate for bed planting resulted in higher yields compared to bed planting with high seed rate. Regarding irrigation water application, the bed planting treatment had the lowest irrigation water application followed by the broadcasting plus ridging and drilling on flat in both seasons. The bed planting irrigation water use efficiency (IWUE) was the lowest in the first season. However, with lower seed rate and the bed planter improvement in the second season bed planting resulted in the highest IWUE. Therefore, bed planting could be considered as one of the methods for wheat production in Sudan's Vertisols with water savings provided that suitable seeding machines are made available and an optimum seed rate is determined.

Introduction

Wheat production has been introduced in the central clay plain in irrigated governmental schemes of Gezira (168,000 ha), New Halfa (25,200 ha) and Rahad (18,900 ha). The soil is Vertisols and the climate is semi-arid. The crop is grown in the winter season during the period November to March. The winter season is shorter and warmer than those of traditional wheat producing areas in the world, and has frequent hot spells. One of the major problems that face wheat production in the irrigated schemes is crop establishment, which arises from bad distribution of the first irrigation water into the fields especially under bad

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Table 1 Average physical and chemical properties of soils in the Gezira Research Station Farm

Property	Value	Property	Value
Coarse sand, g/kg	50	N, mg/kg	0.01
Fine sand, g/kg	70	Ca CO3, g/kg	20
Silt, g/kg	210	EC, mS/cm	< 3
Clay, g/kg	440	SAR	5
pH paste	7.7	Soluble NA, mmol (+)	12
Organic C %	0.3		

leveling. The soil is heavy clay with very low infiltration rate, therefore, water stands for a long period of time causing germination failure as a result of aeration impairment (Ageeb, 1986).

According to availability of seeding equipment in irrigated schemes, there are various methods for wheat crop planting after land preparation. In the Gezira and Rahad schemes, farmers are used to broadcasting seeds manually. Some farmers use 80 cm spaced ridges to cover the seeds with the soil and others use a local-made tractor mounted heavy tool bar with corrugations for combing the soil. The covering of seeds with the corrugated heavy tool bar results in shallow and poor seed coverage with the soil, which causes the washing out of seeds during the first irrigation. In the New Halfa scheme, farmers tend to use the wide level disc equipped with a seeder box for wheat sowing. The setting of 120 cm beds with small furrows in between or 80 cm spaced ridges follows this operation. The objectives of beds and ridges setting after crop sowing were to facilitate field irrigation, minimize the risk of water logging and prevent crust formation. However, for 120 cm beds, the crop in the centre of the bed always suffers from draught as a result of insufficient soil moisture. Due to the adverse effects of these sowing methods, the recommended wheat seed rate for all irrigated schemes is 143 kg/ha (Technical packages, 1991). Earlier investigations and recent findings (A/Wahab et al, 1994) indicated that the seeding rate as low as 95 kg/ha can be sown without yield reduction with the use of wide level disc with a seeder box and the seed drill. With a seed rate of 129 kg/ha El-Awad (1993) found that the use of seed drill resulted in significantly higher crop emergence in comparison with the use of wide level disc equipped with a seeder box, but no differences in number of heads or yields were detected. Because of tillering capacity of wheat crop, the use of lower seed rate is agronomically feasible with the use of seeding machine and economically sound due to the high cost of seeds.

Because of the limited number of available wheat seeding machines and tractors, the simultaneous operations for wheat crop establishment, which are seeding operation and ridging, always result in delaying of crop sowing.

More than 90 % of wheat cultivated area in Mexico is under bed planting system (Sayre and Ramos, 1997). The main reasons for adopting this system is that it improves water management, facilitates pre-seeding irrigation, provids opportunity for initial weed control prior to planting, allows better stand establishment, makes it possible to perform inter-bed mechanical weed control during early crop cycle, uses lower seed rate, reduces crop lodging, reduces herbicide dependence and facilitates hand weeding.

The objectives of this study were to modify a seed drill for combination of 80 cm bed setting and wheat sowing in three rows at a spacing of 15 cm on the top of the bed in one single pass so as to facilitate manual weeding and to evaluate the effects of bed planting with different seed rates on wheat crop growth and yield. And, also the quantification of water savings and irrigation water use efficiency.

Materials and Methods

The experiment was carried out at the Gezira Research Station Farm (14º 24' N, 33º 29' E and 407 m altitude) in 2001/02 and 2002/03.

Fig. 1 The modified bed planter rear view during field testing in the first season

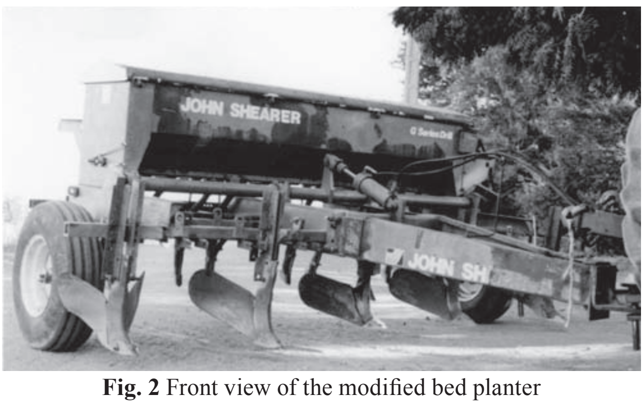


Fig. 2 Front view of the modified bed planter

The soil is typic chromuserts, fine, smectitic, isohyperthermic, which is characterized by swelling when wet and shrinking when dry. The physical and chemical properties of the Gezira Research Station Farm soil to a depth of 30 cm as determined by El Tom (1972) are shown in **Table 1**.

Mechanized Operations

No appropriate seed drill for bed planting is available in the Sudan. Therefore, for bed planting method, an old John Shearer seeding machine was repaired and modified to form the beds and wheat crop sowing in one single pass. It was modified by adding 3 ridger bodies in the center of the machine and two small rectangular hollow bars were welded to the left and right sides where another two ridger bodies were attached making a five-body ridger (**Fig. 1**). The ridger bodies were of adjustable wings. The distance between the ends of the two wings was reduced to 34 cm for each body. Then the bodies were set at 84 cm apart to result in suitable beds with small furrows in between. In the second season the original seed furrow openers of the machine were removed and replaced by disc-type seed-furrow openers, which had been provided from a scraped Oztarim seed drill. The furrow openers were installed so as to produce a desirable row spacing of 15 cm and three rows per bed. All the other furrow openers were removed and their corresponding openings inside the seed box were sealed. The width of John Shearer seeding machine was 336 cm. It was a trailed and consisted of horizontal hydraulic piston for lowering and raising the attached bodies and seed furrow openers (**Fig. 2**).

Land preparation was carried out in the two seasons by the use of a tandem disc harrow with 420 cm working width and with two gangs in the front and rear. The front gang consisting of 9 notched discs with 58 cm disc plate diameter. The rear gang consists of 10 plain disc plates with 59 cm diameter. Then the land was leveled with automatic scraper.

In the first season the experiment was laid out in split plot design with 3 replications. Subplot size was 9.8 x 28 m. Prewatering and no prewatering were the main plots and the following sowing methods were the subplots:

1- Bed planting (BP) with 95 kg/ha using the modified John shearer machine. 2- Broadcasting + ridging (BC+R) with 143 kg/ha. 3- Seed drilling on flat (SD) with 143 kg/ha.

As the results of the first season indicated that there were no significant differences between the prewatering and no prewatering treatments, they were eliminated from the experiment in the second season. More seed rates were tested in the second season. Therefore, the experiment in the second season was laid out in randomized complete block design with 4 replications. Subplot dimensions were 10 x 20 m. The following sowing methods were tested:

1- Bed planting (BP1) with 126 kg/ha. 2- Bed planting (BP2) with 92 kg/ha. 3- Seed drilling (SD1) with 143 kg/ha. 4- Seed drilling (SD2) with 95 kg/ha. 5- Broadcasting + ridging (BC+R) with 143 kg/ha.

In both seasons, the first irrigation was given in the first week of December. Urea at the rate of 2N and super phosphate at the rate of 1P were applied before the second irrigation. The crop was irrigated fortnightly. Wheat (local variety Debeira) was sown.

In the first season, the applied irrigation water was measured using a flow meter between the first and the last (8^{th}) irrigation. While, in the second season, soil moisture was monitored between the first and the 5^{th} irrigation cycles. The grain yield and the 1,000 seed weight were determined in both seasons. Crop emergence/m^2, plant height and plant population/m^2 were also measured in the second season.

Results and Discussion

Modified Machine Performance

The Grain yield and yield components during the first season were taken as a measure for the performance of the modified machine. Where the lower yield of the BP treatment indicated the poor performance of the planter during the first season as will be explained in the following sections. In the second season the introduction of the disc furrow openers greatly improved the performance of the machine, although there were no significant dif-

Table 2 Effects of wheat planting methods on grain yield and 1,000 seed weight in the first season 2001/02

Main plot treatments	Grain yields, kg/ha				1,000 seed weight, g			
	Sowing method			Means	Sowing method			Means
	BC+R	SD	BP		BC+R	SD	BP	
Pre-watering	2,896	2,091	1,479	2,155 NS	31.0	29.6	25.7	28.7 NS
No pre-watering	2,444	2,597	1,395	2,145 NS	29.0	30.7	26.7	28.8 NS
Means	2,670 a	2,344 a	1,437 b		30.0 a	30.1 a	26.2 b	
SE ±	188.2				0.81			
CV %	21.4				6.9			

BC+R: Manual broadcasting followed by riding, SD: Seed drill, BP = Bed planting, NS: Not significant at P < 0.005 level. Means followed by different letters are significantly different at P < 0.05 level according to Duncan's Multiple Range Test ferences in the yields and the tested parameters resulting from the BP treatment compared with the other treatments. The improvement had brought about a positive increase in yields from significantly lower values in the first season to significantly similar yields in the second season, especially with low seed rate.

Grain Yields

The analysis of variance in the first season (**Table 2**) showed that the main treatments (prewatering and no prewatering) had no significant effects on grain yield. The modified machine has shown poor performance in terms of grain yield due to insufficient time for testing. The sub plot treatments were highly significant with the BC+R and SD treatments producing higher yields compared with the BP treatment. Mean separation indicated that the main reason was the significant reduction on the 1,000 seed weight for the BP treatment.

With respect to the second season, non of the crop growth parameters (crop emergence/m^2, plant population/m^2, plant height, 1,000 seeds weight and grain yield shown in **Table 3**) were significantly affected by the different sowing method treatments. Although the insignificantly lower grain yield (1921 kg/ha) was obtained with bed planting (BP) and high seed rate (126 kg/ha), the reduction in the seed rate by about 27 % resulted in an increase of grain yield by about 15 %. The lower grain yield with high seed rate for BP system was probably due to the high competition between plants within the same row. This result agreed with El-Awad findings (2002), who reported that a higher wheat yield was obtained with combined operation machine and lower seed rate.

Water Management

Total Applied Irrigation Water

The crop received 8 irrigations in the first season. The total irrigation water applied was measured using a flow meter from the first irrigation to the last. The total applied water in the first season is given in **Fig. 3**. It is clear from **Fig. 3** that the prewatering treatment reduced the amount of total applied water for the BC+R and BP treatments while the amounts of added irrigation water were high for the SD treatment in both pre and no pre-watering treatments. Also the BP with no pre-watering had the lowest total irrigation water. This supports the assumption that BP saves irrigation water because of the smaller ridge and better control over the larger 80 cm ridge or flat sowing especially when land leveling is a problem.

In the second season the applied water is calculated from water balance equation as the soil moisture is measured just before and after each irrigation. Knowing that there is no deep drainage in the heavy clays of Gezira and no capillary rise from water table and in the lack of runoff due to the gentle slope (Abdelhadi et al, 2000) the water balance equation can be written as:

$\Delta S = I + P - ET$, ...(1)

where ΔS is the change in soil moisture storage (mm), I is the irrigation applied (mm), P is the precipitation (mm) and ET is the evapotranspiration (mm). Since there is no rain in winter, the soil balance can be written as:

$\Delta S = I - ET$, ...(2)

where ET can be estimated from crop coefficient and climatic data measured within the site according to Allen et al. (1994). The total water applied in the second season from the first irrigation and up to the 5th is depicted in **Fig.4**.

The figure indicates that the BP treatments (high and low seed rates) had the lowest total applied water

Fig. 3 Total applied irrigation water in the first season

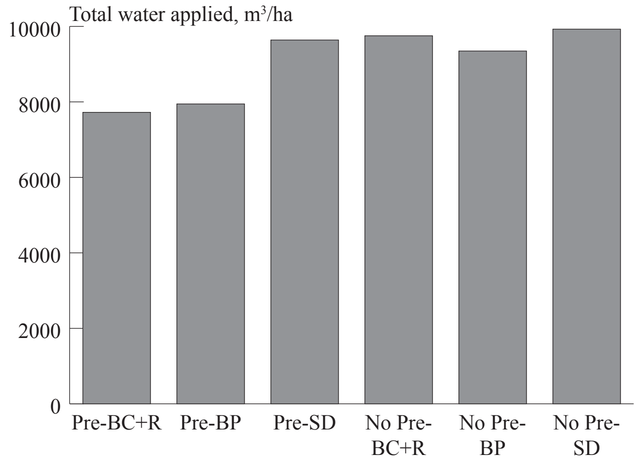
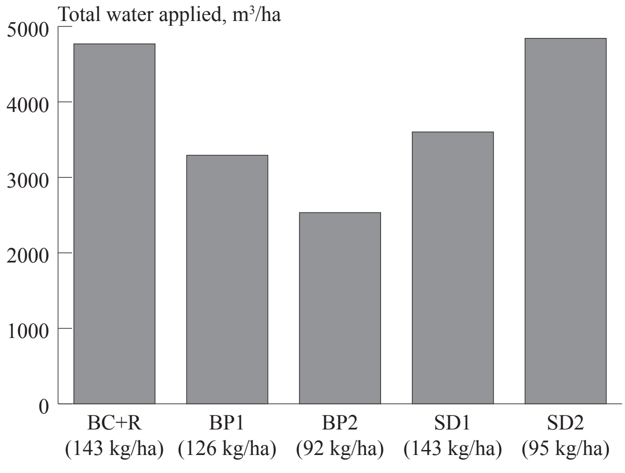


Fig. 4 Total applied water (1st to 5th irrigation) during the second season



Pre: Pre-watering, No Pre: No pre-watering, BC+R: Manual broadcasting + ridging, BP: Bed planting and SD: Seed drilling on flat compared with the other treatments (BC+R and SD). The water savings for the BP1 with higher seed rate in comparison with that of BC+R reached 31 % while BP2 with lower seed rate resulted in 47 % water saving with high yield (**Table 3**). Similar comparison between BP1, BP2 and SD1 and SD2 resulted in 9 and 30 % water savings respectively.

Table 3 Effects of wheat planting methods on wheat crop performance

Treatment	Crop emergence/m^2	Plant Population/m^2	Plant height, cm	1,000 seed weight, g	Grain yeild, kg/ha
BP1 (126 kg/ha)	343	356	70	29	1,921
BP2 (92 kg/ha)	305	387	71	31	2,226
SD1 (143 kg/ha)	301	348	71	31	2,902
SD2 (95 kg/ha)	262	309	70	31	2,992
BC+R (143 kg/ha)	312	372	71	33	2,462
Means	305	354	71	31	2,501
SE ±	50.1	43.8	1.8	1.0	357.8
CV %	23	17	4	5	20
Significance level	NS	NS	NS	NS	NS

BP: Bed planting, SD: Seed drill, BC+R: Manual broadcasting followed by ridging, NS: Not significantly difference at P < 0.05 level

Irrigation Water Use Efficiency (IWUE)

Government policy makers are interested in higher yields per unit of water applied. In this context the calculation of IWUE is based on the definition of Howell et al (1994). He defined IWUE as the ratio of crop yield (t ha^{-1}) to seasonal irrigation water (mm) applied including rain. It is important to mention here that the total applied water was measured between the first and the last irrigation (8 irrigations) while, in the second season the water balance equation was used to determine the applied water between the first and up to the 5th irrigation. We could not monitor the soil moisture during the last two irrigations in the second season. **Fig. 5** shows the IWUE values for the different sowing methods in the first season. It is clear from **Fig. 5** that the BP treatment resulted in lower IWUE because of the significantly lower yields. However, pre-watering seems to have improved the IWUE for both BP and SD treatments. Previous research work has indicated the positive effects of pre-watering for better stand establishment and wheat yields however, the lack of sufficient irrigation water due to competition with other summer crops renders this practice impracticable. The values obtained for IWUE are in agreement with those obtained by Salwa Yagoub (1997) who used the same local wheat variety (Debeira).

Fig. 6 shows the IWUE for the second season between the first and 5th irrigation cycles. The BP2 with lower seed rate resulted in the highest IWUE followed by the SD1 (recommended practice) while the SD2 and BP1 resulted in similar IWUE followed by the BC+R treatment. The increase in IWUE over the recommended practice (SD1) and the traditional practice (BC+R) was about 7 and 40 %, respectively.

Conclusions

Wheat bed planting system could be adopted in the irrigated Vertisols of Sudan with reduced seed rate and more efficient irrigation water utilization if the suitable seeding machine is made available. Due to high competition among different water users during the winter season and the high cost of wheat seeds, bed planting with suitable machine and low seed rate (92 kg/ha) could im-

Fig. 5 Irrigation water use efficiency IWUE during the first season

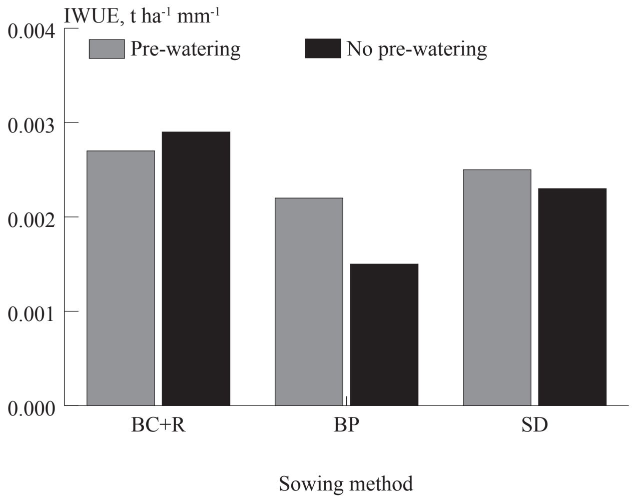
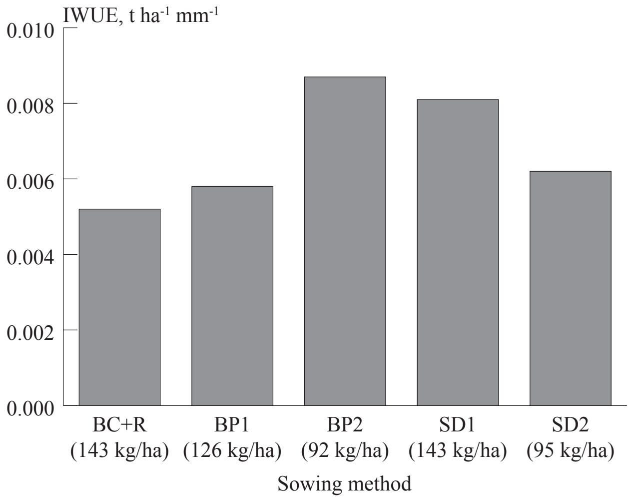


Fig. 6 Irrigation water use efficiency IWUE during the second season



prove water management, reduce time of seeding and reduce seed rate by about 36% over the recommended (143 kg/ha).

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Subsoiling - a Strategy to Combat Water Scarcity and Enhanced Productivity of Groundnut Crop

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Abstract

This study was conducted because of constant lowering of groundwater and variability in quantity and frequency of rainfall in Saurashtra and in most parts of Gujarat as well as in all of India. Subsoiling technology provides an opportunity to enhance the crop production particularly under dry period conditions.

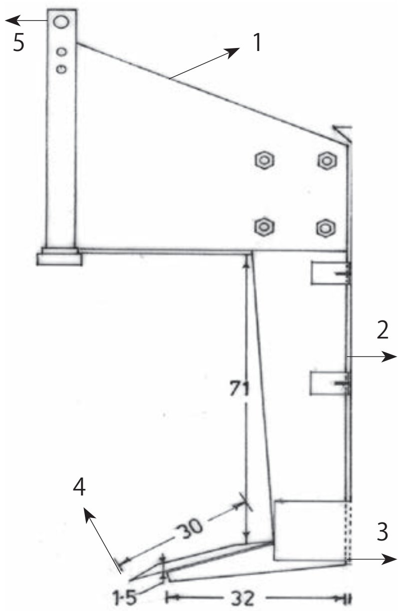
Subsoiling (fracturing of subsoil without inversion) is considered to be an energy consuming operation but it provides a significant increase in yield of various crops (groundnut as a case study) particularly under dry period conditions. It also minimizes soil compaction related problems. Subsoiling operation provides a solace in crisis to farmers in South Saurashtra Agro climatic Zone where average annual rainfall is only approximately 750 mm with erratic rainfall and water scarcity at critical times.

Field experiments conducted at various locations of this area indicated that, as the dry period increases, the benefit of subsoiling is more significant and evident. But, it cannot be presented in generalized form. Subsoiling also seemed to be effective in conserving moisture, minimizing bulk density, enhancing root development, reducing draft during digging/uprooting, weed control and, above all, increasing crop yield.

Introduction

Human beings, particularly in arid and semiarid regions, are almost at the verge of facing "drinking water famines", which is not recorded or heard of in the historical past of India. In Gujarat, the problems are so acute that about 75 % of the villages

Fig. 1 Tractor drawn conventional subsoiler



Treatments; T1 = Subsoiling in between two furrows of groundnut alternatively (alternate patla), T2 = Control
Parts; 1 = Frame, 2 = Shank, 3 = Bottom, 4 = Reversible blade, 5 = Hitch point

suffer from water scarcity, particularly in drought years. The ground water, which is the main source of irrigation, has been over exploited.

Under the circumstances it has become imperative to look more rationally at the water availability through precipitation, innovative methods of recharging the rain water into the under ground aquifers and to develop more efficient water use technologies. Subsoiling technology is one established technology among them.

Methodology

A tractor mounted conventional subsoiler (**Fig. 1**) was operated before onset of monsoon to a depth of 35-45 cm, or even more in a few cases, either in between two furrows (Patla), alternatively, or in the furrow it self (**Fig. 2**).

Field observations like rainfall,

Fig. 2 Tractor drawn conventional subsoiler in operation

Fig. 3 Rainfall distribution versus crop growth and field practices

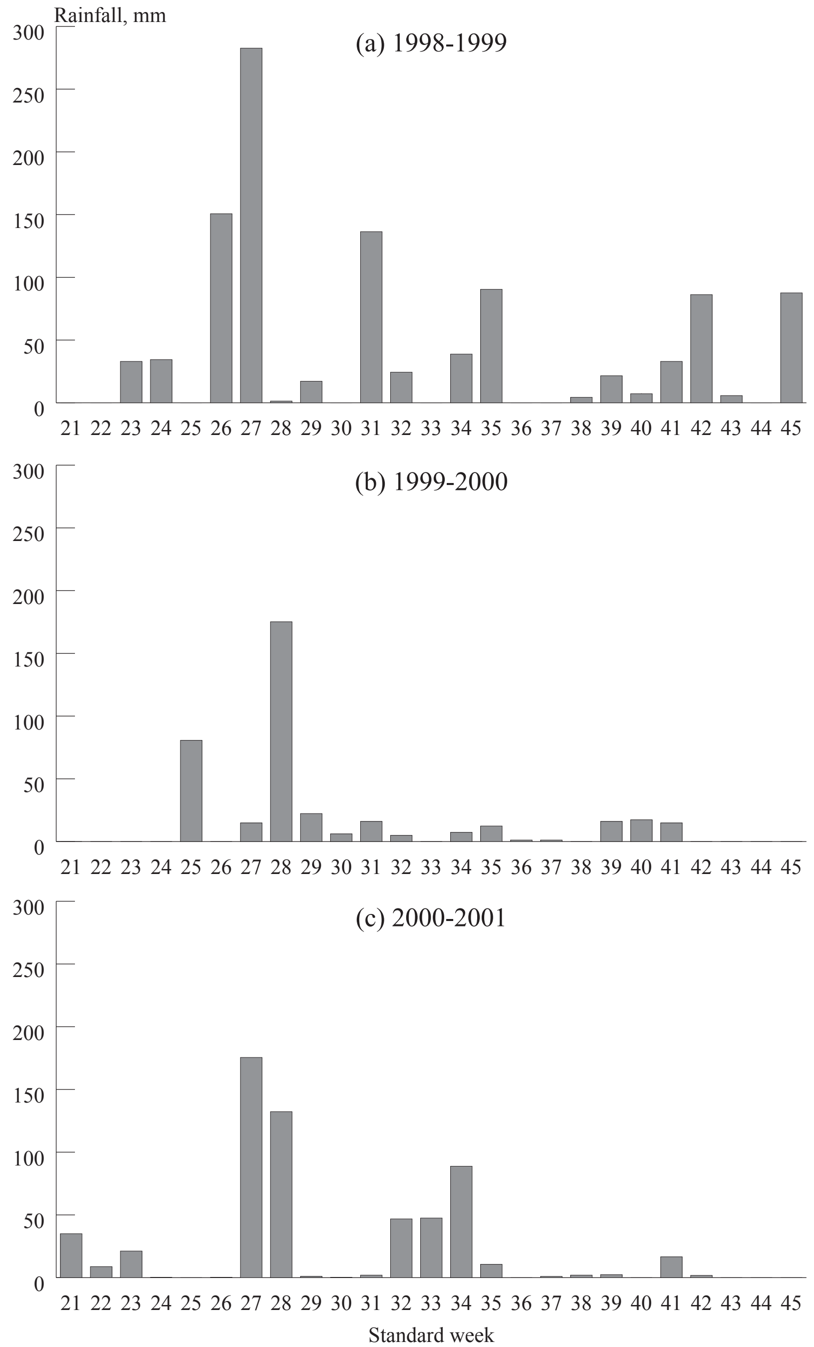


Table 1 Standard week wise rainfall data

Standard week	Rainfall, mm		
	1998-99	1999-00	2000-01
21	0.0	0.0	35.0
22	0.0	0.0	8.8
23	31.8	0.0	21.2
24	34.7	0.6	0.2
25	0.0	81.0	0.0
26	151.4	0.0	0.3
27	282.3	14.8	175.5
28	1.3	174.4	132.3
29	16.4	23.6	1.1
30	0.2	6.8	0.2
31	136.4	16.8	2.0
32	25.3	5.2	46.8
33	0.8	0.0	47.5
34	38.5	7.8	88.8
35	89.7	13.2	10.6
36	0.0	1.3	0.0
37	0.0	1.8	1.0
38	4.6	0.0	2.0
39	21.2	16.1	2.4
40	8.4	18.8	0.0
41	32.8	14.5	16.6
42	86.0	0.0	1.8
43	6.5	0.0	0.0
44	0.0	0.0	0.0
45	88.5	0.0	0.0
Total	1,056.8	396.7	594.1

moisture content, bulk density, penetration resistance and yield were taken. General field observations like vegetative growth, root development, feasibility and comfort of the operator during subsoiling operation and draft during uprooting, including weed growth, were also observed from time to time.

Design of Experiment

A non-replicated large plot, sample plot technique (Completely Randomized Block Design) was employed in laying out field experiments at various farmers' fields in the nearby area.

Rainfall Distribution Pattern

The rainfall data of the three years 1998-99, 1999-2000 and 2000-01, as shown in **Table 1**, indicated that rainfall occurring during the "pegging" stage, which was the critical stage in groundnut growing period, was comparatively quite low in the year 1999-2000 followed by 1998-99 and 2000-01 (**Table 2** and **Fig. 3**).

The annual rainfall was highest in the year 1998-99 followed by 2000-01 and 1999-2000. In 1998-99 the rainfall was normal at 1,049 mm and in 1999-2000 the rainfall was quite below the normal at 396 mm with moisture stress at flowering and pegging stage. In 2000-01 the rainfall was 595 mm, which is below normal with stress after flowering stage.

This distribution pattern of rainfall indicates that moisture stress during pegging stage adversely affects yield.

Effect of Subsoiling on Soil Penetration Resistance

A cone penetrometer has been employed for measuring soil penetration resistance in the upper (0-7.5 cm), middle (7.5-15.0) and lower (15.0-above) soil layers (**Table 2**).

The penetration resistance was 22 %, 63 % and 6 % less for upper, middle and lower soil layers, respectively, than that in control plot after 20 days of sowing.

At the time of harvesting, the upper soil layer was in a loosened stage in the subsoiled plots as compared to the control plot and the soil maintained its looseness in middle and lower soil layers. This indicated that it may be helpful in root development and water intake into the soil.

Effect of Subsoiling on Draft during Interculturing and Weed Growth

A dynamometer was attached with bullock drawn implements for draft measurement during interculturing and groundnut digging operations. **Table 4** indicated that about 17 % and 9 % reduction in draft was observed during interculturing and groundnut digging operations, respectively. This provided opportunity for better root development as well as less stress on the operator

(continued on page78)

Table 2 Rainfall distribution versus crop growth and field practices

Year	Date of subsoiling	Date of sowing	Critical crop stage (standard week)			Total annual rainfall, mm
			Flowering	Pegging	Harvesting	
1998-99	12-06-1998	20-06-1998	29 to 32	32 to 35	45	1,056.8
1999-00	05-06-1999	21-06-1999	29 to 32	32 to 35	43	396.7
2000-01	08-06-2000	03-07-2000	31 to 34	34 to 37	43	594.8

Table 3 Effect of subsoiling treatments on soil penetration resistance with increase in depth

Sr. No.		Depth (cm)	Average soil penetration resistance, kg/cm^2		Remarks
			Subsoiling	Control	
A	1	0-7.5	2.919 (22.8)	3.784	After 20 days of sowing
	2	7.5-15.0	2.972 (63.0)	8.030	
	3	15.0-45.0	11.625 (6.4)	12.415 (up to 32.5 cm)	
B	1	0-7.5	9.343 (38.2)	15.120	At the time of harvesting
	2	7.5-15.0	9.767	Did not penetrate	
	3	15.0-45.0	18.150	Did not penetrate	

Note: Figures in parenthesis indicate percentage decrease in penetration resistance over control

Table 4 Draft during interculturing and weed growth in various treatments

Item	Subsoiled strip	Control strip	Remarks
Draft, kg	54.10 (17.85)	65.86	After 23 days of sowing
Draft, kg	50.18 (9.45)	55.42	At the time of crop harvesting
No. of weed per squre meter	70 (250)	175	After 23 days of sowing

Note: Figures in parenthesis indicate percentage decrease in draft and weed over control

Table 5 Effect of subsoiling on yield of groudnut crop location: Govt. Seed Farm, Timbawadi

Year	Yield, kg/ha		Increse in yield, %	Additional cost of operation, Rs./ha	Advantage due to subsoiling, Rs./ha	Rainfall, mm	Remarks
	Subsoiling	Control					
1998-99	1,815	1,494	21.5	625	4,185	1,049	Normal
1999-00	957	778	23.0	625	2,058	396	Stress at flowering & pegging
2000-01	846	350	142.0	625	6,815	595	Stress after flowering

Evaluation of Practical Training in Uganda's Agricultural Engineering Carriculum

by

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Abstract

One of Uganda's development goals is to reduce the proportion of the population living in absolute poverty through a program for modernizing agriculture. In light of the need to provide the manpower required for implementing the development program, the practical component of the undergraduate agricultural engineering (AE) curriculum at Uganda's Makerere University was reexamined. In this investigation, a survey of students and alumni/employers was conducted with respect to practical training educational needs. The findings show that the curriculum needs adjustments as a first step towards producing graduates that are more of job creators and less of job seekers.

Introduction

Up until the 1980's, the majority of fresh engineering graduates in Uganda were offered jobs by either the civil service or government controlled (parastatal) corporations. The macro-economic changes initiated in late eighties began to take root in the nineties and a key element of these reforms was privatization and/or divesture of parastatal corporations. The current development strategy is underpinned by poverty eradication through a private sector-driven program for modernizing agriculture (PMA).

Poverty in Uganda is mainly a rural phenomenon as in many sub-Saharan countries. Forty four percent of the rural population lives below the absolute poverty line compared with the 16 % urban dwellers (Appleton 1999). Since more than 85 % of the population live in rural areas, the interventions to be implemented under PMA should bring about meaningful changes. Statistics from a 1999 Uganda Participatory Poverty Assessment Report has shown a strong association between poverty reduction in rural settings and the ability to produce and market traditional cash crops, such as coffee (Anon, 2000). Households in the food crop sector experienced only modest rates of poverty reduction compared to those producing cash crops (Okurut et al, 1999).

The goal of the government is to reduce the proportion of the population living in absolute poverty from a level of 44 % (1997) to below 10 % by year 2017. Guiding visions and missions have been developed in the following areas: (1) research and technology development, (2) agricultural advisory services, (3) agricultural education, (4) access to rural finance, (5) agro-processing and marketing, (6) natural resource utilization and management, and (7)

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supportive physical infrastructure (e.g., roads, electricity, water and communication). The priority areas and their associated vision and mission are presented in **Table 1**. If properly trained, engineering graduates, especially agricultural engineers should constitute a critical manpower component of the work force needed for the realization of the missions of research and technology development, agro-processing and marketing, natural resource utilization, and supportive infrastructure. However, for agricultural engineers to provide components of the desirable manpower, they must be trained to have a mindset that is responsive to the emerging "customers" made up of new private (mostly foreign) owners of the former parastatal corporations and the small scale (mostly rural) self-employed workers in the informal sector (Anon, 2000). The emergence of the new customers is not only limited to Uganda but is a common trend in sub-Saharan Africa (Mushi, 1999).

Exposure to the new customers through practical training (expanded classroom) provides a vehicle for students to integrate the new customer realities with concepts taught in the classroom and thus enhance student responsiveness to the new customers' needs. The concept of the expanded classroom is not new. Today most colleges and universities all over the world have arrays of programs that may be categorized under the heading of expanded classroom. In North America, programs such as service learning, internship, cooperative education, and study abroad are presented by institutions or academic staff (faculty) to be the main vehicle for integrating the student's experiences into the concepts introduced in the classroom (Katula, 1999; van Vuuren and Pouris, 1992). In the Agricultural Engineering (AE) curriculum at Makerere University, the expanded classroom is fulfilled through practical training and capstone design/research courses. It is mainly through these courses that students use theory in solutions to practical problems and learn first hand the context and nature of challenges they will face when they graduate.

Table 1 shows a typical AE program of study. The degree program normally extends over a period of four years and each year consists of two 17 week-semesters and one 10 week-recess term. A full time student carries a minimum of 15 and not more than 30 credit units. Practical training courses include AE 192 Workshop Practice, AE 290 Industrial Training I, AE 380/AE 381 Industrial Training II/Industrial Case Study, and AE 442 Design Project (capstone). The course descriptions are provided in **Table 2**.

This article reports the outcome of an investigation into how well the industrial training component of the AE curriculum at Makerere University prepares students to provide the workforce needed for the realization of the PMA mission. Results of a survey of views and attitudes of students and alumni/employers in relation to practical training education and needs of emerging customers are described.

Table 1 A typical program of study for a degree in agricultural engineering at Makerere University

Year	1st Semester	2nd Semester	Recess Teram
Year 1	Engineering Mathematics I (4[1]) Engineering Drawing (4) Engineering Mechanics (4) Electrical Engineering I (4) Intro. To Ag. Engineering (3)	Engineering Mathematics II (4) Mechanics of Materials I (4) Introduction to Computers (4) Thermodynamics (4) Fluid Mechanics I (4) Ag. Engineering and Development (3)	Workshop Practice (2)
Year 2	Engineering Mathematics III (4) Mechanics of Materials II (4) Machine Drawing (4) Agricultural Surveying (4) Crop Science for Engineers (4)	Engineering Mathematics IV (4) Theory of Machines (4) Computing Programming (4) Hydraulics and Hydrology (4) Material Science (4) Soil Science for Engineers (4)	Industrial Training I (3)
Year 3	Climatologic and Modeling (3) Farm Power (3) Agric. Process Engineering I (3) Rural Electrification (3) Animal Science for Engineers (3) Food Science for Engineers (3)	Soil and Water Engineering (4) Farm Machinery (3) Agricultural Process Engineering II (3) Rural Structures & Environment (5) Design of Machine Elements (4)	Industrial Training II (5) Industrial Case Study (3)
Year 4	Systems Analysis (3) Eng. Experimental Design (3) Intro. Finite Element Method (3) Small scale Manufacturing Principles (3) Irrigation Theory & Practice (3) Soil & Water Engineering (3) Rural Extension for Engineers (3)	Engineering Seminars (1) Design Project (5) Design of Agricultural Machinery (3) Design of Processing Equipment (3) Management of Econ. for Engineers (4) Elective[2] (3)	

[1]The numbers in brackets are credit units (CU). One CU is equivalent to one contact hour per week per semester.
[2]Electives to choose from: Land Evaluation for Irrigation (3), Earth Moving Equipment (3), Land Policy and Law (3).

Methodology

A survey instrument was developed to assess the extent to which the learning objectives in the industrial training courses were met. The instrument was divided into three parts: (1) background information; (2) outcome achievement and perceived career importance of the main learning objectives for each of the courses; (3) employer/alumni suggestions and comments. The survey contained structured 5-point Linkert items (1= low degree of achievement and 5 = high degree of achievement) for outcome and career importance questions. Also, included were free answer questions for background information and open-ended questions regarding alumni/employer suggestions and comments. Prior to its use, the instrument was reviewed by several AE academic staff (faculty) members.

The 2000/2001 AE enrollment consisted of 17 first, 20 second, 24 third and 18 fourth year students. A total of 45 (9 alumni/employer and 36 students) survey forms were completed. Thirty six students out of 61 first, second and third year students represented a reasonable return for statistical accuracy. Some students were not reached due to time constraints. Fourth year students were not polled because the survey was conducted during the 2001 recess term after their graduation. Eighty seven percent of the respondents were male, an accurate reflection of the student population gender distribution. Students were evenly distributed on the basis of academic status (24.4 %, first year, 28.9 % second years and 26.7 % third years). A key requirement for all the practical training courses was at least two academic staff visitations. The purpose of these visits was to ascertain that the students were engaged in activities consistent with the course objectives. Also, the visits were used to interact with the employer and to receive feedback on the student performance. Academic staff members administered the questionnaires to students during one of the required industry visits.

Table 2 Practical training courses in Uganda's agricultural engineering curriculum

Course	Description
AE 192 Workshop Practice	Training is carried out at the university workshop. The eight modules covered include: (1) Manual practice - tools, marking off, measurement and fitting; (2) Machine shop processes - turning, milling, grinding, drilling; (3) Fabrication practice - screw fastening, riveting, welding, adhesive bonding, and fabrication; (4) Electrical house wiring - regulations, consumer circuits and wiring accessories; (5) Diagnostic and repair of electric appliances; (6) Repair of electronic equipment - e.g., radios and TVs; (7) Building construction - brickwork, concrete work, trusses and plumbing; (8) Building finishing processes - painting vanishing and decorating.
AE 290 Industrial Training I	During the recess term of the second year, each candidate goes to an industry/firm for training. The main emphasis of training understands the place where training is done. Examples of particular areas for understanding could include organization, machinery, operations, materials, energy, and waste management, byproduct utilization
AE 380/381 Industrial Training/Industrial Case Study	During the recess term of the third year, each candidate receives industrial training in agro-based industries. The main emphasis of training and thus the case study is technical planning and/or application of general engineering knowledge in solving constraints in industry. With in the above outlined AE 380, the candidate chooses an engineering problem. The topic may be chosen by the candidate and discussed by the Engineer under whom the candidate is training. Problems, which might be tackled, may range from technical feasibility to modification of an existing production process. A technical report is prepared.
AE 442 Design Project	A project devoted to an independent investigation and report on agricultural engineering topic. The report should reflect the capacity of the candidate to apply theory and practical knowledge of agricultural engineering. It is carried out under the supervision of a faculty member The project is carried out from any of the following areas: (1) farm power and machinery, (2) soil and water engineering, (3) agricultural process engineering, and (4) structures and environment.

Results

The numerical responses for each course were averaged and are presented in tables Table 3A (AE 192), 3B (AE 290) and 3C (AE 381/381). The verbal interpretation of the outcome assessment numerical scale provided to the students was: 1 - not acceptable, 2 - below expectations, 3 - meets expectations, 4 - exceeds expectations, and 5 - far exceeds expectations. The verbal interpretation of the career importance numerical scale provided to students was: 1 - irrelevant, 2 - less important, 3 - important, 4 - very important, 5 - extremely important. Results for each course are discussed below.

Workshop Practice (AE 192)

In AE 192, training (eight modules) is carried out at the university workshop. Agricultural and mechanical engineering students are combined and both receive the same training. Training involves theory and hands-on practice. In addition to the topics shown in Table 3A, the students added surveying (10 students), motor vehicle repair/

technology (7 students), highway maintenance (6 students) and electrical installation (4 students) in the "other" category. This was puzzling because these topics are not covered in AE192. It is possible that these are areas perceived by students to enhance their future placement prospects.

The average outcome achievement scores were all below 3 as shown in **Table 3a**. Five out of nine items were scored above 3 under career importance. Repair of electronics equipment particularly stood out as it was scored below 1 under outcome achievement and below 2 under career importance. These scores were attributed to the students not fully realizing the relevance of these modules to their careers and in some cases the situation may have been made worse by covering theory with minimal hands-on exposure. Evidence in support of this analysis came from the following representative free comments.

"We should begin ...other than ending with the mechanical module. Most of the work covered in electrical module is not relevant to agricultural engineering and should be eliminated. Instead, we should be introduced to agricultural machinery and production at an earlier stage. If possible, agricultural engineering students should have their workshop practice separately from the mechanical engineering students."

"Some of the workshop practices were not fully realized. Too much theory without practice only helps in report writing, yet there is a need to do more practical, e.g., varnishing, decorating plumbing, etc."

According to the academic staff, the two main objectives of AE 190 are to provide, through a hands-on approach, an appreciation of the skill required to make any envisioned (designed) product a reality and to begin to develop technical communication skills through engineering sketches and report writing. The most common free comment from the students was that the duration of the time for each module was not adequate; they expressed preference for training in agricultural workshops or firms as opposed to the university workshop. One student summed up the above sentiment as follows.

"I am requesting the administration to consider providing frequent industrial tours as this will expose us to the field work. They should send us to busy industries where we can learn both engine work and production work instead of concentrating on the activities like welding at the university workshop. Educate us on how to do the final project work (AE 442) early enough other than waiting till the 4th year. Expand the training areas to include the Rice Scheme in Lira District or Kinyara Sugar Works."

In its present form, AE 190 is perceived by students not to address their practical training aspirations. But from the academic staff viewpoint, the two main objectives are being met. By recognizing that the time allotted is too short, the students are appreciating the skill required to produce an acceptable product. To facilitate the development of technical communication skills the students are provided with a record book with daily record, weekly record and drawing sheets that are graded. The grades assigned for the past three years were normally distributed confirming that the communication objective was being net. The discontent expressed by the students may be attributed to differences in expectations; students may be feeling that they need more time to, for example, become good welders, which is not the intent of the course. Perhaps the course objectives and academic staff expectations need to be clearly articulated to the students at the outset.

Industrial Training I (AE 290)

The learning objectives of AE 290 are to appreciate the work environment through understanding of the interrelatedness of organization charts, machinery, operations, materials, energy, waste management, and byproduct utilization. Also, students are expected to continue to develop their communication skills using tools similar to those used in AE 190. The numerical responses from AE 290 students are presented in **Table 3b**. Comparatively, students in AE 290 were more satisfied

Table 3a Outcomes and career importance scores for AE 192[1]

AE 192 Workshop Practice	Outcome/ Achivement	Career Importance
A. Practical understanding of:		
Manual practice (tools, marking off, measurement and fitting)	2.88	3.48
Machine shop processes (turning, milling, grinding and drilling)	2.35	3.85
Fabrication practice (screw fastening, riveting, welding, adhesive bonding, etc.)	2.76	3.98
Diagnosis and repair of electrical appliances (motors, heaters, etc.)	1.58	2.49
Repair of electronic equipment (radio, TV, etc.)	0.96	1.53
Building construction (brickwork, concrete work, trusses and plumbing)	2.25	2.59
Building finishing processes (painting, varnishing and decorating)	2.43	2.12
B. General understanding of how simple engineering components/stuructures are made	2.76	3.83
C. Gaining meaningful hands-on experience	2.45	3.92

[1]Five-point Linkert scale (1 = low and 5 = high) was used and shaded areas highlight scores below the middle of the scale

with their training than students in AE 192.

Assessment of working in multi-discipline environments, practicing on a global scale and use of information and communication technology were scored below 3. It was surprising that computing technology and relating societal/cultural issues were not deemed important to the student careers. In AE 120 (Introduction to Computers), students are introduced to organization and characteristics of computers including number and coding systems, operation systems and working environments and standard applications such as word-processing spreadsheets and databases. Students are not exposed to the computer as a tool for accessing engineering information worldwide or as a tool for design. This may explain why computing technology in communication and engineering analysis and design was not considered that important for their careers.

As the economic and political barriers to global trade come down, engineers, irrespective of location, will find increased opportunities to practice or interact globally (Anon. 2001). For engineers in developing countries, this may mean increasingly working for foreign employers - who are accustomed to use of information and communication technology in all aspects of their business. Lack of access to technical information in developing countries has in the past kept engineers in these countries in isolation. Easy access through the World Wide Web and the Internet should begin to equalize the playing field, if students are provided with training on how to fully utilize the information resources at their disposal. Lack of information mentioned above and the changing customer base were evident as pointed out by one of the students below.

"Though there was an exclusive study of the various machines and their modes of operation, some machines did not have proper user' s manuals, while others had manuals and other operation instructions in foreign languages like German. There were problems in understanding instructions from the Asian supervisors due to language problems."

With most of the parastal corporations being acquired by foreign concerns, interactions with foreign employers will increase. Relating to others from different cultural backgrounds will take on a more important dimension. Although AE students take a course in Agricultural Engineering in Development (AE 191), where they explore the role and responsibility of their profession in national development, they did not consider relating engineering to societal/cultural issues of importance to their career. This raises the question of how well students are prepared to play leading roles in the implementation of some of the PMA mission and in particular, raising the population living in absolute poverty from a level of 44 % (1997) to below 10 % by year 2017. The AE curriculum needs to clearly identify the self-employed rural worker in the informal sector as a true emerging customer that needs the attention of the engineer while at the same time emphasis is placed on producing job creators as opposed to job seekers.

Table 3b Outcomes and career importance scores for AE 290[1]

AE 290 Industrial Training I	Outcome/ Achivement	Career Importance
A. Application of and ability to:		
Work on a project as part of a term	4.0	4.14
Work with others from different disciplines	2.71	4.0
Work with others from different ethnic/cultural backgrounds	3.46	3.53
Relate engineering to societal/cultural issues	3.0	1.94
B. Application of the importance of:		
Practicing engineering on a global scale	2.78	3.74
Environmental aspects of engineering practice	2.94	2.99
C. An understanding of the integration of:		
All engineering aspects of the enterprise	3.52	3.4
Engineering and other aspects of the enterprise	3.43	4.0
D. An understanding of and ability to:		
Use a wide range of equipment	3.45	3.59
Use computing technology in communications	0.67	2.1
Use computing technology in engineering analysis/design	0.64	2.23

[1]Five-point Linkert scale (1 = low and 5 = high) was used and shaded areas highlight scores below the middle of the scale

Industrial Training II (AE 380) /Industrial Case Study (AE 381)

The main objective in AE 380/381 is to apply general engineering knowledge in solving problems in industry. The student is expected to choose an engineering problem in concurrence with the industry-supervising engineer. Problems, which might be tackled, may range from technical feasibility to modification of existing production process. In addition to the log, a report of no more than 20 pages about the engineering problem tackled is required. Credit for the report is given separately as AE 381.

AE 380 students generally recognized the importance of all assessment criteria for their career with scores of approximately 3 or better as shown in **Table 3c**. The majority of the outcomes were scored below 3, with lowest scores associated with functioning on cross-disciplinary teams (1.31) and developing engineering specification (1.68). The low engineering specification score was attributed to the fact that students are not exposed to design methodology formally. It seems like the industrial supervisor is expected to provide guidance in this area. Unfortunately, most supervisors are not providing the training. Under the circumstances, it is understandable for the students to feel inadequately prepared as reflected in several free comments below.

"I appreciate the many training fields one is exposed to in this firm, but there is lack of competent personnel to pass on the technologies to the student engineer. This is because; most of the workers learned on job and the highly educated are diploma (associate degree equivalent) holders. A student engineer can get a lot done from this place, if well qualified personnel were in place."

"We lacked enough supervision and guidance on project identification."

Despite the general low outcomes assessment, there were several positive comments from the students. For example one student wrote:

"This training has helped me visualize what practical engineering problems are and prompted me to look for solutions. The training has exposed me to various engineering sections helping me to have a wide variety of knowledge. However, I have not been given a chance to work on a problem independently with minimum assistance mainly because the company is concerned with my training slowing down the production process. I think it' s important that students be given a chance to identify a problem, its cause and also provide a solution independently to gain practical experience in the discipline. Also, some of my suggestions/solutions to solve the problem identified were not tried out."

"Working or training upcountry and more especially in rural community is quite challenging and interesting."

"The training has given me a broad perspective of what engineering is about like time management especially as related to project engineering, health and safety at work, competition in business necessitating certification by certain standards like ISO 9000, environmental sensitivity and knowing how to work with people of different races."

The low scores may be more related to the fact that at this level, it is difficult to get exposure to all the outcomes in one place. But definitely, the students questioned the qualifications of some of their industry supervisors. Paying close attention to the qualifications and background of the industry supervisor in process for selecting firms for student training should eliminate this problem.

Design Project (AE 442) and Alumni/Employers' Observations

After AE 380/381, the students are considered ready to start their capstone design (AE 442 Design Project). AE 422 is devoted to independent investigation and report on agricultural engineering topic, reflecting the capacity of candidate to apply theoretical and practical knowledge of agricultural engineering. The project is carried out under the supervision of AE academic staff member. Approximately a third of the projects are extensions of industrial case study (AE 381). The remaining are ideas from AE academic staff. In the past three years, the majority of the projects have been research- as opposed to design-based. This is reflected in the internal grading guide (not shown) that places emphasis on research paper report format.

Alumni/employers provided the following evaluation aspects not covered on the questionnaire: (1) ability to work with local communities and understand how the community views the engineering solution, (2) design of system components and marketing it (entrepreneurship), (3) time management, (4)

Table 3C Outcomes and career importance scores for AE 380/381[1]

AE 380/381 Industrial Training II and Case Study	Outcome/ Achivement	Career Importance
A. An understanding and ability to:		
Gather date from print, human or other sources	3.46	2.77
Design and conduct experiments	1.89	3.65
Analyze and interpret gathered and/or experimental data	1.98	3.39
B. An understanding and ability to:		
Function on a cross-disciplinary team	1.31	2.77
Function on cross-functional teams	2.07	2.93
C. An understanding and ability to:		
Identify engineering problems or needs	3.54	4.13
Develop engineering specifications	1.68	3.87
Solve engineering problems or develop and evaluate solution concepts	2.46	3.61
Design a system, component, or process to meet a desired need	2.13	3.53
Recognize situations that call for high professional and ethical responsibility	2.64	4.0
D. An understanding and ability to:		
Communicate orally (informal and prepared talks)	3.53	4.0
Communicate using engineering drawings or graphics	1.89	3.27
Communication using written reports	1.82	4.01

[1]Five-point Linkert scale (1 = low and 5 = high) was used and shaded areas highlight scores below the middle of the scale

working with technicians. Additional comments are provided in **Table 4**. While the concept of AE 192 was strongly endorsed, the facility where it is conducted was questioned. Although in developing countries technology is usually imported and not locally developed, engineers still need to be well trained in the design function because most imported technologies still require modifications to properly work in the new environment (Teitel, 2000). As observed by one of the employers, one of the elements that seemed to be missing throughout student training was working in teams. Teams add a powerful dimension to regular work places as they combine the skills and creativity of a diverse number of people in order to produce an effective outcome (McGourty and DeMeuse, 2001).

Recommendations

Under the current global economic realities, where knowledge is changing rapidly (Jarvis, 2000), the workforce needs to be prepared to respond in kind. In Uganda's development strategy, the agricultural engineer needs to be sensitized to the notion that he/she needs to view himself/herself as more of a job creator than a job seeker in order to serve a nontraditional customer base. The AE curriculum can be used as a vehicle to bring about the above paradigm shift. As shown in **Table 1**, the current curriculum is very well grounded in the engineering fundamentals and traditional applications of these fundamental. The recommendations offered below are simple adjustments specific to industrial training, meant to serve as a first step towards the overall goal of preparing the students to meet the needs of the 21st century customer.

Hands-on instruction in accessing engineering information worldwide should be introduced. With the new Makerere University Internet link (MAKNET), a small investment in a PC laboratory together with instruction material is all that is needed.

Formal instruction in design methodology should be offered. This could be taught and practiced through the use of a simple team projects drawn from the new customer base, especially the self-employed workers in the informal sector. Students could learn problem definition, conceptual design techniques, analysis procedures for detailed design, and working in teams. If the course is offered before AE 290, students will likely find more meaning in the practical training and will be better equipped to address problems from non-industrial sources. Also, academic staff development in this area is needed to build capacity and to ensure the sustainability of the offering.

The learning objectives of AE 380/381 should not be limited to "to applying general engineering knowledge in solving problems in industry" but should be opened up to problems in "society." This will enable the inclusion of the self-employed workers of the informal sector in the customer base. Students could be placed with Non-Governmental Organizations that have traditionally served this constituent. Academic staff could provide the necessary oversight to ensure that all the learning objectives are met.

Whenever possible, students should be allowed to receive training for both AE 290 and 380 from the same company/location. This could help in acquiring skills and gaining the trust of the supervisor and thus contributing more. Since the majority of the graduates do not go on to graduate school, students may be served better by providing AE 442 projects that are design- as opposed to research-based.

Lastly, exchange programs with neighboring countries should be looked into to enable students to receive industrial training away from Uganda. Linkages among AE degree granting institutions in sub-Saharan Africa could be established to facilitate the industrial exchanges. This will not only expand the customer base, but will also provide a broader and more global perspective to the students and thus better prepare them for the 21st century.

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Table 4 Additional comments from alumni/employers

1. The industrial training also exposes you to the reality of engineering skills related to the field as compared to lecture notes and theories.
2. Much emphasis should be put on the above course (AE 192) since the employer and your career demand for it. No compromise. There is a need for more serious workshop than the one at the Faculty of Technology. The above course to me seems like its one of the core courses for any engineer. It provides the basics of a practicing engineer.
3. Industries in third world countries use imported technology. We are more of users than designers that is why we don't score highly wherever there is design. Private companies are always on the look out for ready technology to use. It's only government that can appreciate design and innovations.
4. We should encourage people to team up and do one project. This helps them in a way because outside class things are handled in a group. For example, three students could be assigned to one project.
5. Students pursuing undergraduate courses could benefit from industrial training if the courses are merged together with real experience in factories. Visits to factories could be made prior to a particular course unit if there is any identified practical experience in such a factory related to that course unit.
6. The training is focused on practical skills only

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(Continued from page70)

Subsoiling- a Strategy to Combat Water Scarcity and Enhanced Productivity of Groundnut Crop

and the bullocks. In addition, it was also observed that the number of weeds per square meter in the subsoiled plot were quite low.

Effect of Subsoiling on Yield of Groundnut

The pattern and distribution of rainfall and the collective effect of moisture content, bulk density and penetration resistance due to subsoiling on yield is significantly evident by **Table 5**.

In 1998-99 there was near normal rainfall, whereas during 1999-2000 and 2000-01 significantly low and erratic rainfall occurred. The yield obtained in the three years was observed to be 21.5 %, 23 % and 142 % higher, respectively, as compared to the control. Thus, subsoiling provided a gain of Rs.2,058 to 6,819 per hectare.

Experimental observation obtained in this area indicated that the benefit of subsoiling was more significant and evident as dry period increases, provided that at critical stages of crop growth sufficient moisture has been retained in the soil by any means. Thus, the gain due to subsoiling cannot be presented in generalized form.

Conclusions

1. Subsoiling operation either before onset of the monsoon or just after harvesting of the previous crop gives better results.
2. Advantage obtained due to subsoiling will be more evident as the dry period increases.

Suggestion

Instead of a single tine conventional subsoiler, two subsoiler tines will be fitted with the tractor drawn cultivator frame for the subsoiling operation. (work is under progress at the department).

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Performance Evaluation of a Tractor-Operated Sugarcane Harvester

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Abstract

A tractor-operated sugarcane harvester was designed, constructed and tested. Results of the tests showed that the effective field capacity ranged from 0.4 to 0.5 ha/h, and decreased with increase in crop density and extent of stem lodging. In the high crop density fields, the field efficiency averaged 65.82 %. It, however, increased with decrease in crop density and stem lodging. The material capacity increased from 7.75 to 21.04 t/h as the crop yield increased from 15.48 to 53.28 t/ha. The topping unit efficiency was significantly affected by crop density and extent of stem lodging, while the base cutter efficiency was not significantly affected.

Introduction

The sugarcane (Saccharum officianarum) plant is one of the cheapest sources of energy giving foods with low unit of land area per unit energy produced. It is the oldest and cheapest source of raw material for sugar manufacturing (Purseglove, 1988). Sugar from the cane is used to sweeten tea, kunu, fura da nono and akamu local food drinks in Nigeria, as well as bread, snack foods and beverages. Residual sugarcane stalks are used as fuel in sugar factories or as raw materials in the manufacture of paper, fiber board and card board. Filter cake from sugar factories is used to improve soil fertility. Other by-products of sugarcane processing are used as appetizers in animal feed or as raw materials in the industrial manufacture of alcohol.

In Nigeria, sugarcane is grown in plantations or by small holders, who sell the stalks for chewing. The harvesting of sugarcane is mainly carried out manually (Jika, 1994) and this has made the operation to be both labour intensive, risky and full off losses. As a result, it has posed an impediment to the large scale production of this economic crop.

Mechanical devices for harvesting sugarcane stems such as whole-stick harvesters and chopper harvesters have been introduced but their use could not be sustained for lack of spare parts. Moreover, it has been noted by Clayton (1969) that cane stalks harvested by chopper harvesters tend to deteriorate quickly. In order to overcome the above problems, there is the need to develop appropriate technology equipment that will ease the harvesting of sugarcane and reduce the amount of money spent on the importation of sophisticated machines for which spare parts are not available.

This paper reports the performance evaluation of the tractor-operated equipment designed and fabricated for harvesting sugarcane stems.

Description and Operation of the Equipment

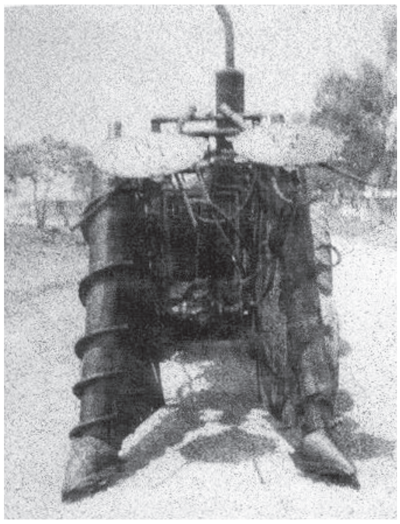
Sugarcane Harvester Description

The sugarcane harvester consists of two main units, namely, the tractor front-mounted crop divider and topping unit, and the rear mounted base cutter unit. The crop divider and topping unit as mounted on the tractor front is shown in **Fig. 1**. The crop divider system consists of two rotary dividers made of 2 mm thick metal sheets which were cut, folded and welded into conical pipes with the ends closed using flat discs. Each divider has spiral rod welded in windings to the body to form a conveying system. A drive shaft runs through each divider and is integrated to it by welding at the ends of the pipe. Each divider is mounted vertically with the lower end shaft running in a bearing enclosed by the base shoe. The upper end shaft runs through a bearing carried in a housing that is mounted vertically on a square pipe, into a hydraulic motor, which is powered by a hydraulic system held in position on the tool frame.

The topping unit consists of two metal discs that are mounted vertically to rotate horizontally above the crop divider. Each disc carries seven metal blades on its edge and is coupled to a hydraulic motor. They are carried by booms which are connected to a hydraulic ram cylinder and held in position on the tool frame. The topping unit is mounted on top of the crop divider system. An assembly drawing of the unit including the part list is shown in **Fig. 2**.

The functions of the crop divider include the separation of sugarcane stems on the row being harvested from the ones on adjacent rows; lifting of the stems that have logged and are sprawled on the ridge and guiding them up to the topping unit for the tops to be cut; guiding of the stalks to fall under the tractor for cutting and pushing aside the stems from outer rows so that the tractor will not trample on them. The leafy tops of the sugarcane plant are a source of contamination to the sugarcane juice. They contain less sucrose and more water; hence they have to be removed. The topping unit is incorporated to the machine to perform this function. The crop

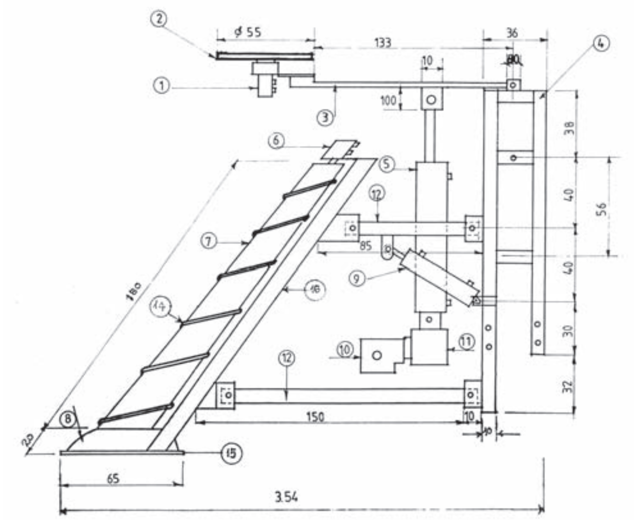
Fig. 1 Sugarcane harvester crop divider and topping unit as mounted on the tractor front



divider system and topping unit assembly are both powered by a hydraulic power system consisting of hydraulic motors, hydraulic rams and cylinders, hydraulic pumps and valves. The hydraulic circuit of the system is presented schematically in **Fig. 3**. The hydraulic system is also used to raise the unit to its transport position during transportation.

The base cutter unit is mounted on the rear of the tractor by means

Fig. 2 Assembly drawing of the crop divider and topping unit



1. Hydraulic motor, 2. Topping disc and blades, 3. Boom, 4. U channel 762 x 101.6, 5. Hydraulic ram cylinder, 6. Hydraulic motor, 7. Rotary divider, 8. Shoe, 9. Hydraulic ram cylinder, 10. Hydraulic pump, 11. Pump mounting bracket, 12. Rectangular tube 70 x 40, 13. Pipe ø 50 mm, 14. Pipe, 15. Shoe bar, 16. Square pipe 50 x 50

Fig. 3 Schematic diagram of machine hydraulic circuit

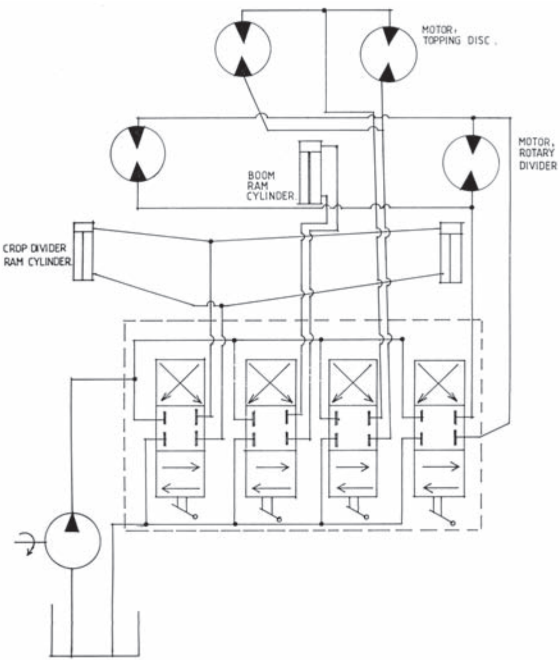
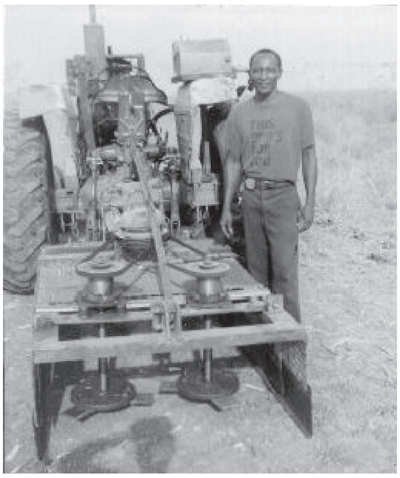


Fig. 4 Base cutter discs with blades and serrated vertical knives

Fig. 5 Base cutter unit as hitched to the tractor, showing the cutter disc and blades



of the three point linkage. It is PTO driven and consists of two horizontal cutting discs mounted on vertical drive shafts. Each disc is fitted with three cutting blades and three vertically mounted serrated plates (**Fig. 4**). The disc drive shafts run through deep grooved bearings in housings mounted on the tool frame to belt and pulley arrangements that are connected to the pulley of a gear box. The gear box is mounted on the tool frame in such a way that the shaft converts a rotational motion from the horizontal to the vertical direction. A universal joint is used to connect the gear box to the tractor PTO shaft. The tool frame which is made of U-channel steel and covered by the side with steel sheet and on top by wire mesh. The base cutter unit as hitched to the tractor using the three point linkage is shown in **Fig. 5**. This figure also shows the cutter discs and blades as well as the disc drive mechanism. The assembly drawings of the unit and its part list are shown in **Fig. 6** (**a** and **b**).

Sugarcane Harvester Operation

The crop divider and topping unit is mounted to the tractor front and the hydraulic system checked and connected to the hydraulic control arrangement To operate the harvester. The base cutter unit hitch points are coupled to the tractor three point linkages and the universal joint coupled to the gear box input shaft is connected to the tractor PTO shaft. The operator mounts the tractor, uses the hydraulic control lever to raise the crop divider and topping unit to transport position and the three-point linkage control lever to raise the base cutter unit to transport position. The tractor with the harvester units is moved into the field and the row at which harvesting is to commence. The crop divider and topping unit and base cutter unit are lowered to operational levels and the hydraulic motors and PTO shaft are actuated to run the units and the tractor is moved forward into the field.

As the equipment is moving through the field, the rotary divider, which is powered by the hydraulic motor, separates the sugarcane stems on the row being harvested, picks up the logged stems and lifts them to the rotating topping discs that are also hydraulically powered and appropriately located to cut off the sugarcane tops. After this, the rotary divider guides the stalk to fall under the tractor for the next operation which is the cutting of the

Fig. 6a Base cutter unit assembly (front view)

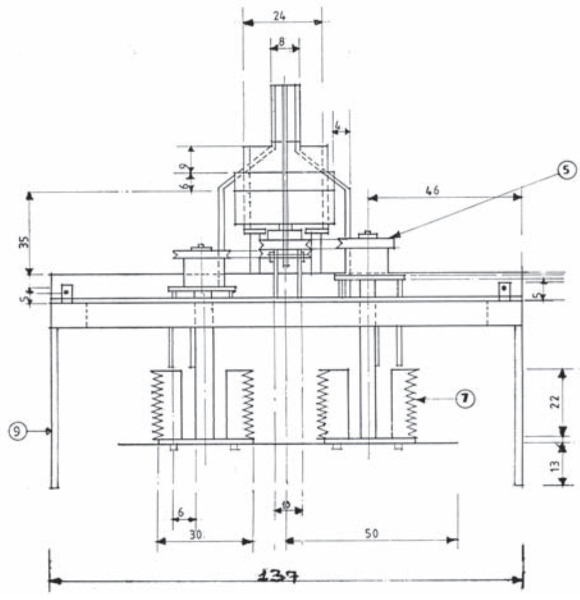
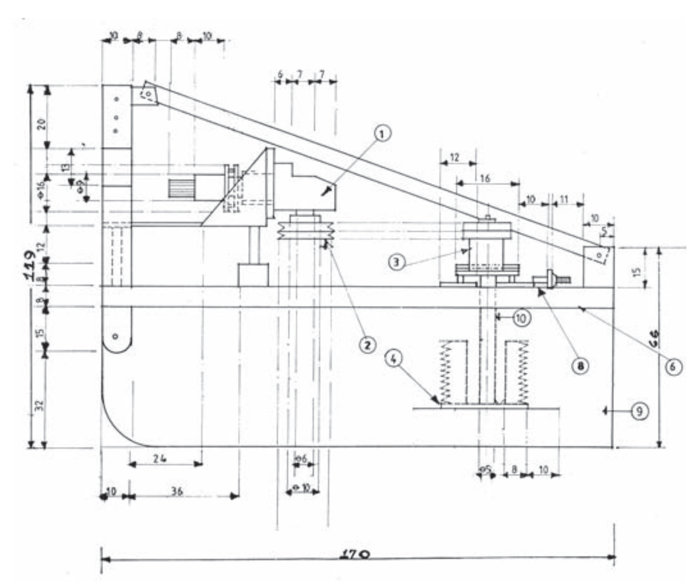


Fig. 6b Base cutter unit assembly (side view)



1. Gear box, 2. Double sheave pulley, 3. Disc drive shaft bearing housing, 4. Base cutter disc and blade, 5. Disc drive pulley, 6. Tool frame of U channel, 7. Serrated plate, 8. Disc cutter blade, 9. Side cover, 10. Disc drive shaft

stalk at the base. The rotary motion of the tractor PTO is transmitted through the gear box of the base cutter unit to the cutting disc. The gear box shaft changes the direction of the motion from horizontal rotation to a vertical one and rotates the cutting discs' vertical shafts which in turn run the discs. As the tractor continues its forward motion, the topped stalks that have fallen under the tractor come in contact with the base cutter discs. The rotating disc blades shear the stalk at the base and the vertically mounted serrated plates push the cut stalks backward as the forward motion continues. The cut stalks are picked manually and loaded into a wagon. **Figure 7** shows the tractor operated sugarcane harvester coupled to the tractor in readiness for field operation.

Performance Tests and Evaluation

The prototype sugarcane harvester was tested in the clayey loam field of the Savannah Sugar Company, Numan in Adamawa state of Nigeria. Tests were carried out to evaluate the machine performance in terms of effective field capacity, field efficiency, material capacity, topping unit efficiency and base cutter efficiency. Three fields A, B, C with different sugarcane population were selected. Field A had high sugarcane population with the cane stems highly logged and sprawled on the rows. Fields B and C had erect cane stems but less crop density than A. These fields were employed for the tests to determine whether crop density and extent of lodging have effect on the machine performance indices.

The effective field capacity of the machine was determined by dividing each field (A, B and C) into three portions each containing ten rows of sugarcane. The length of each row was measured and the area of each portion determined in hectares. The machine was operated to harvest the portions of the fields in a random manner. The time taken to complete the harvesting operation in each of the field portions was recorded. The effective field capacity, C_e, was determined using the equation.

$$C_e = \frac{A_p}{T_k} \quad \text{.....................................(1)}$$

where A_p = area of the field portion (ha) and

T_b = time taken to complete the harvesting of sugarcane in field portion (h)

The average speed of the operations was noted, the operational width of the machine was determined and the field efficiency calculated from the equation (Kepner et al, 1978) which related the effective

Fig. 7 Tractor operated sugarcane harvester coupled to the tractor in readiness for field operation

field capacity to the field efficiency. The equation is stated as

$$C_e = \frac{SWE_f}{1000} \quad \text{................................(2)}$$

from which

$$E_f = \frac{1000C_e}{SW} \quad \text{................................(3)}$$

where E_f = field efficiency, %,

C_e = effective field capacity, ha/h,

S = speed of operations, km/h; S = 3 km/h, and

W = operational width of equipment, m; W = 2 m.

The material capacity of the machine defined as the mass of material handled by the equipment per hour, was determined using the equation.

$$C_m = C_eY \quad \text{.......................................(4)}$$

where C_m = material capacity, t/h and

Y = sugarcane yield, t/ha.

To determine the topping unit efficiency, one hundred sugarcane stems harvested from five rows in each selected field, were randomly picked and examined for proper topping.

Table 1 Sugarcane harvester field performance indices

Field	Row length, m	Area, ha	Time, h	Yield, t/ha	Effective field capacity, ha/h	Field efficiency, %	Material capacity, t/ha
A_1	210	0.294	0.73	53.12	0.4027	67.117	21.39
A_2	215	0.300	0.80	53.68	0.375	62.50	20.13
A_3	206	0.289	0.71	53.04	0.407	67.833	21.587
Mean	210.33 (3.682)	0.294 (0.005)	0.747 (0.039)	53.28 (0.285)	0.40 (0.014)	65.82 (2.363)	21.04 (0.645)
B_1	240	0.366	0.68	16.55	0.494	82.33	8.176
B_2	236	0.3314	0.65	16.02	0.510	85.00	8.17
B_3	245	0.342	0.72	16.94	0.475	79.17	8.04465
Mean	240.3 (3.682)	0.37 (0.004)	0.68 (0.029)	16.50 (0.377)	0.49 (0.014)	82.167 (2.383)	8.13 (0.060)
C_1	180	0.252	0.45	15.13	0.56	93.33	8.473
C_2	200	0.275	0.60	15.87	0.458	76.33	7.268
C_3	194	0.268	0.55	15.45	0.487	81.167	7.524
Mean	191.33 (8.38)	0.265 (0.02)	0.53 (0.06)	15.48 (0.30)	0.50 (0.04)	83.61 (7.15)	7.75 (0.518)

Numbers in parentheses are standard deviations

The properly topped stems were taken as those whose tops were cut at the desired point of machine setting. The improperly topped stems were those that required further topping and the ones topped below the setting. The topping unit efficiency was calculated using the following expression.

$$E_{tp} = \frac{N_p}{N_f} 100 \text{ ....(5)}$$

where E_{tp} = topping unit efficiency %,

N_p = number of properly topped sugarcane stems, and

N_t = total number of sugarcane stems.

The base cutter efficiency was determined by selecting one hundred sugarcane stems from each of the fields and harvesting them using the machine. The harvested stalks were then separated into those that were completely cut at the base, those that were uprooted and those that were not cut. The base cutter efficiency was calculated using the following expression:

$$E_{bc} = \frac{N_c}{N_t} \text{ x } 100$$

where E_{bc} = base cutter efficiency, %,

N_c = number of stems completely cut, and

N_t = total number of sugarcane stems.

Results and Discussion

The results obtained on machine field performance indicators are presented in **Table 1**. From the table, it can be seen that the effective field capacity of the machine varied from 0.5 to 0.4 ha/h and decreased with increase in cane yield and degree of stem lodging. This could be attributed to the increase in time utilized in carrying out the harvesting operation in high density fields. The increase in time consumption in the high density fields may have been due to the large volume of materials that need to be handled and the incidence of logged stems, which required time to be lifted as well as several stoppages necessitated by the presence of stems that fell across the row. According to Jika (1996), 16 labourers are required to harvest a hectare of sugarcane in an eight-hour day. This machine can harvest between 3.16 and 4.01 ha of sugarcane in an eight-hour day, a job which will require from 51-65 labourers.

The field efficiency also decreased with increase in crop density and lodging of stems. In the field with high crop density and high extent of stem lodging, the field efficiency averaged 65.82 %, which is within the range specified for field chopping equipment (Kepner et al, 1978). At lower crop density, the field efficiency was as high as 83.61 %. Factors that affected the field capacity must have also been responsible for the response of the field efficiency.

The material capacity of the equipment increased from 7.75 to 21.04 t/h as the crop yield increased from 15.48 to 53.28 t/ha. This shows that the time spent in carrying out the operation was used mainly for productive work.

The topping unit performance efficiencies are presented in **Table 2**. The efficiency was significantly lower at field A with high crop density and extensive stem lodging, than at fields B and C where the crop population was less dense and the stems were erect. In the field with logged stems, there were occasions in which the logged stem picked up by the crop divider, were not appropriately positioned for the operation of the topping discs. This must have given rise to higher topping inefficiency recorded in field A.

The base cutter performance efficiencies are presented in **Table 3**. Performance efficiencies recorded in both fields with high crop density and high extent of stem lodging were comparable to those obtained in fields with low crop density. The crop density and extent of stem lodging did not seem to significantly affect the base cutter efficiency and the number of stalks that were uprooted.

Table 2 Sugarcane harvester topping unit efficiency

Field	Row	Number of stalks propely topped	Number of stalks not propely topped	Total number of stalks	Percentage of propely topped stalks
A	1	81	19	100	81
	2	78	22	100	78
	3	79	21	100	79
	4	80	20	100	80
	5	80	20	100	80
Mean	-	79.6 (1.02)	20.4 (1.02)	100 (0.00)	79.6 (1.02)
B	1	94	6	100	94
	2	95	5	100	95
	3	96	4	100	96
	4	98	2	100	98
	5	97	3	100	97
Mean	-	96.0 (1.414)	4.0 (1.414)	100 (0.00)	96.0 (1.414)
C	1	87	13	100	87
	2	90	10	100	90
	3	92	8	100	92
	4	91	9	100	91
	5	95	5	100	95
Mean	-	91.0 (2.608)	9.0 (2.608)	100 (0.00)	91.0 (2.608)

Numbers in parentheses are standard deviations

Conclusions

From the performance evaluation of the tractor-operated sugarcane harvester, the following conclusions could be drawn:

1. The effective field capacity of the machine was between 0.4 and 0.5 ha/h.
2. The effective field capacity decreased with increase in crop population and extent of stem lodging.
3. In an eight-hour working day the machine could harvest between 3.16 and 4.01 ha of sugarcane, a job which would require about 51 to 65 labourers to carry out.
4. In fields of high crop density and high degree of stem lodging, the field efficiency of the machine was within the range obtainable for field chopping equipment.
5. The field efficiency increased with decrease in crop density and decrease in extent of stem lodging.
6. The material capacity of the machine increased with increase in yield.
7. The topping unit efficiency was significantly affected by crop density and extent of stem lodging.
8. The base cutter efficiency was not influenced by crop population and extent of stem lodging.

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Table 3 Sugarcane harvester base cutter efficiency

Field	Row	Number of stalks propely cut	Number of stalks not cut	Number of stalks uprooted	Total number of stalks	Base cutter efficiency, %
A	1	91	3	6	100	91
	2	96	2	2	100	96
	3	94	5	1	100	94
	4	97	3	0	100	97
	5	96	4	0	100	96
Mean	-	94.8 (2.135)	3.4 (1.02)	1.8 (2.227)	100 (0.00)	94.8 (2.135)
B	1	96	2	2	100	96
	2	96	2	2	100	96
	3	95	1	4	100	95
	4	98	2	0	100	98
	5	96	3	1	100	96
Mean	-	96.2 (0.98)	2.0 (0.632)	1.8 (1.326)	100 (0.00)	96.2 (0.98)
C	1	98	0	2	100	98
	2	100	0	0	100	100
	3	97	1	2	100	97
	4	98	0	2	100	98
	5	96	0	4	100	96
Mean	-	97.8 (1.326)	0.2 (0.4)	2.0 (1.265)	100 (0.00)	97.8 (1.326)

Numbers in parentheses are standard deviations

Role of Computers in Eco-Friendly and Sustainable Agriculture of the 21st Century

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Abstract

The rapid advances in the computer and communication technologies and in the agricultural technology have been a boon to farmers. The computer has potential to make agriculture enter into an era of disciplined agricultural production processes wherein it would be possible to escape the extremes of natural vagaries and to ensure profitable and sustainable agricultural production by efficient planning, design and management of agribusiness. In this paper, an attempt has been made to focus on multi-faceted role of computers in the complex agriculture sector. The current and future usage of computers in various disciplines of the agriculture sector is succinctly described. It is demonstrated that the agriculture sector offers numerous opportunities for the use of computers in different disciplines of agriculture, various on-farm and off-farm activities as well as planning and management of agricultural systems. The increasing role of computer and communication technologies in education and rural development is also highlighted. Finally, it is emphasized that the use of new technologies and tools will help meet the daunting challenges ahead and will ensure long-term sustainability of agricultural production in an environmental friendly manner.

Introduction

We are living at one of the turning points in the human history. The engine driving this radical change is nothing but the computer. Agriculture is the primary link between people and the environment. Almost 70 % of the land that is colonized by human beings is used to grow food and fiber and 70 % of the water, globally, is used for irrigation and agriculture. This figure is between 80 and 90 % for developing countries. Agriculture provides livelihoods to over 70 % of the population in most developing nations. Furthermore, very few low-income countries have achieved rapid non-agricultural growth without corresponding rapid agricultural growth (Serageldin, 2000). Therefore, sustainable agricultural growth is an essential element of economic growth in most developing nations.

All the sectors of agribusiness, viz., input supply industries, agricultural production and food processing, and manufacturing and design are gradually becoming more and more dependent on computers. The day-by-day decline in the cost of computers as well as the acquaintance of the cost savings that could be gained by using computers have enhanced the rate of computer adoption. Computers, no doubt, have touched almost all the facets of human life. The useful services that the computer can offer to human beings are immense. Continuously, newer, smaller and yet more powerful, efficient and multi-purpose electronic devices are produced at a galloping rate. New electronics and communication technology are particularly important for the primary food producers because the farmers and growers need more precise and timely information in order to maintain the profitability of their enterprises. It is now a proven fact that computerization improves the quality of work, increases the output, conserves resources and reduces the time delay (Cox, 2002).

The primitive knowledge of crop cultivation has been transformed into modern agriculture through the ages and it is still changing and evolving as per the economic, social and environmental needs (White, 1997). The global food security is threatened by declining productivity, soil salinity/alkalinity, waterlogging, nutrient deficiency, water deficits, water pollution, groundwater depletion, and development of resistance and resurgence in pests (Brown, 2000). It is the need of the hour to achieve water security and food security as well as to ensure sustainable agricultural production. To alleviate the ill effects of excess and under-application of agricultural inputs, a new form of farming popularly known as Precision Agriculture is emerging (White, 1997; Robert, 2001; Zhang et al, 2002). It is a high-tech and knowledge-based farming where precise packages of crop cultivation at micro levels are adopted giving due consideration to the spatial variability of land so as to maximize crop productivity, improve crop quality and on-farm quality of life as well as to minimize environmental damages (Robert, 2001). In addition, the need-based and site-specific approach in precision farming leads to the judicious utilization of various resources. Thus, the precision farming techniques are both intellectually stimulating and economically rewarding. **Figure 1** illustrates the primary features of precision farming. Besides the farm operations, computer application can also help improve the efficiency and quality of our research, teaching, and extension efforts. There is an urgent need to capture the knowledge generated by the vast network of scientists and encapsulate this invaluable knowledge to help in reliable decision-support for solving various agricultural problems of the farmers. In the words of arenowned agricultural expert, Dr. M.S. Swaminathan: "The green revolution was triggered by the genetic manipulation of yields in crops, whereas the ever-green revolution will be triggered by farming systems that can help produce more from the available land, water and labour resources without either ecological or social harm" . In this paper, an attempt has been made to highlight the application of computers and other electronic instruments/equipments in various disciplines of agriculture and their role in ensuring improved and eco-friendly agricultural production on a long-term basis.

Computer Applications in Agriculture

Agriculture is a very vast industry involving five major disciplines: crop production technology, post harvest technology, animal husbandry, dairy technology, and aquaculture. Computers can play an important role in each of these disciplines, which is succinctly described in subsequent sections. In fact, computers could be applied to the agricultural sector from farm planning to marketing, and thus can revolutionize the entire agribusiness. **Figure 2** depicts different aspects of agribusiness where computers and other electronic devices can play a key role.

Crop Production Operations

Crop Establishment

Monitors for seed drills are used in developed countries to alert the tractor driver instantaneously of a blockage in any of the seed tube by a signal that is received in a monitor unit placed in the tractor cab. Additional sensors may be provided to obtain information on the plant density and area covered by the drill as well as the depth of seed placement and the tractor speed. On the similar line, electronic plant thinners are widely used in the Western World. Moreover, the quality of seeds/seedlings can be evaluated by a machine vision system (e.g., Urena et al, 2001).

Fertilizers and Pesticide Application

Electronic sensors can be employed to operate the sprayers with hydraulic nozzles spaced out on booms. These electronic systems ultimately provide the driver with

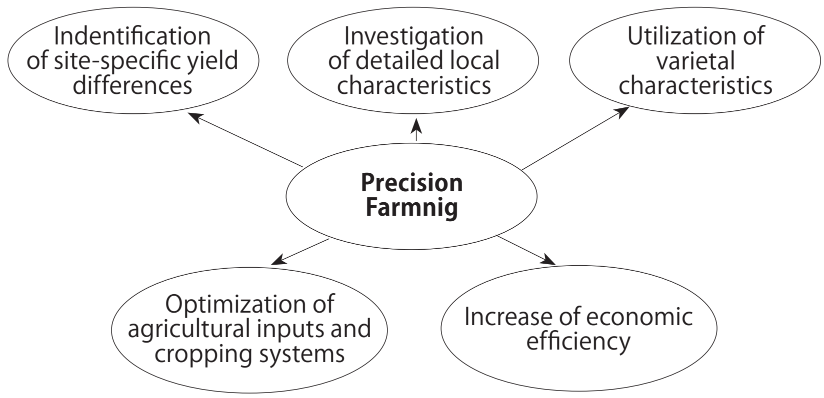

Fig. 1 Primary features of precision farming

information on the application rate of fertilizers and pesticides, performance of sprayers, together with a better or automatic control over flow rates. Besides these, with the provision of fertilizer level detectors (e.g., nitrogen sensor, soil organic matter sensor) and insects/disease detection sensors over the field, a much more efficient and site-specific application of nutrients (Lammel et al, 2001) and pesticides could be possible. For example, 'PC-Plant Protection' is the most widely used PC-based farm level decision support system to control weeds, pests and diseases in Denmark and Europe (Murali et al, 1999). This system is well accepted by the farmers as well as by crop production advisors because of increased profits. Artigas et al (2001) have fabricated and evaluated some ion-sensitive chemical sensors for real-time monitoring of nutrient levels in the soil. It is reported that these sensors have promising future applications.

Furthermore, Tian et al (2002) developed and tested a local-vision-sensor-based precision herbicide application system called 'Smart Sprayer'. They integrated a real-time machine vision sensing system and individual nozzle controlling device with a commercial map-driven-ready herbicide sprayer to create an intelligent sensing and spraying system. The machine vision system was specially designed to work under outdoor variable lighting conditions. Thus, the computer-controlled application of fertilizers and pesticides as per the site-specific need and their real-time monitoring ensure optimal resource utilization, improved crop yields and minimize adverse environment impacts caused by surface water and groundwater contamination and/or nutrient-loss from fields.

Monitoring of Soil, Water Quality and Weather

Soil moisture, suction, density, temperature, nutrient content, pH, salinity, and various ions are salient soil properties that need to be measured in situ instantaneously and accurately in time and space. Several efficient electronic instruments with or without datalogging facilities are available for these soil properties such as TDR and capacitance-based moisture sensors, hydroprobe, water potential sensors, pH sensors, soil temperature and salinity sensors together with NIR (Near Infrared) and Global Positioning Radar (GPR). Low-cost sensors are also being developed for measuring various soil properties (e.g., Bristow et al, 2001). Also, micro-processor-based water quality monitoring systems like HORIBA 23P and Hydrolab facilitate quick and real-time monitoring of salient physical and chemical water quality parameters, including the depth. Furthermore, sensors are also available for continuous and automatic recording of flow in open and closed conduits and of pressure in the closed conduit. Such systems will play an increasingly important role in water resources management.

Real-time monitoring of different meteorological parameters, viz., solar radiation, air temperature, sunshine hours, canopy temperature, barometric pressure, wind speed, rainfall, evaporation and relative humidity can reliably be done by means of different sensors. Electronic sensors with a datalogging facility provide a continuous record of various weather parameters and real-time information, which can also be sent to a PC by using a telemetry system or cables. Such an automated weather monitoring system is popularly known as an Automatic Weather Station. Its use is gradually increasing even in developing countries. Such a real-time monitoring system is also available for river-stage and canal water levels. Furthermore, weather forecast computer models such as General Circulation Model (GCM) help plan agricultural activities, including the scheduling of irrigation. Such detailed and real-time information on weather are very useful for efficient planning, design and operation of agricultural systems. GCM is a useful tool for predicting the global hydrologic impacts on agriculture and environment (Loaiciga et al, 1996).

In addition, the high-level irrigation system automation is achieved by sophisticated computer-based devices, which not only automatically open and shut off pumps/valves, but also offer comprehensive control on the irrigation operation. The pressurized irrigation technology is rapidly growing (Phocaides, 2001) and automated pressurized irrigation systems (e.g., Yitayew et al, 1999) are gradually emerging as standard, efficient, and sustainable irrigation methods in the new millennium (Phene, 1995).

Crop Monitoring

Farmers often need to measure the moisture content of a crop quickly

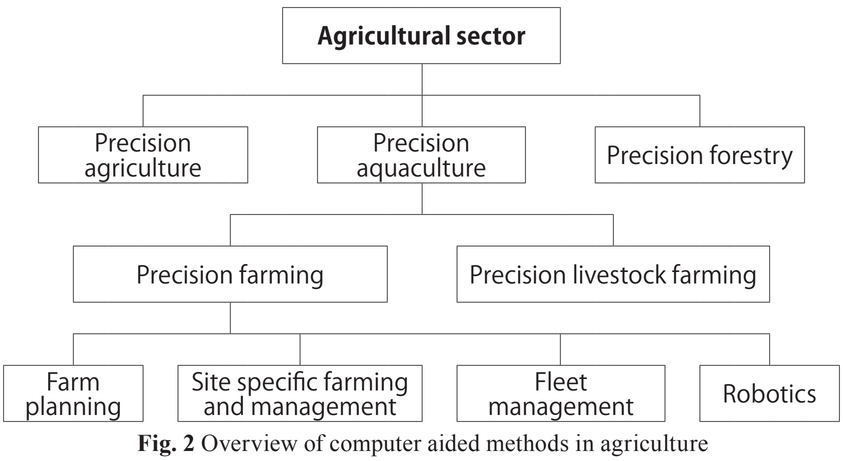

Fig. 2 Overview of computer aided methods in agriculture

and accurately, to help decide the timing of harvesting operations. Various types of microprocessor-based moisture meters for different seeds are available with averaging facilities. Moreover, in some developed nations, yield estimation is one of the functions of computer-based remote sensing apparatus carried by aircraft or satellites. GPS and GIS play a key role in producing real-time chemical input and crop yield maps.

Crop and Fodder Harvesting

The sensors fitted on the self-propelled combine harvester monitor the shaft speed, loads on elements of the system, binfill, grain loss rate, and so on. They provide indications of malfunction or the need for attention through visual/audible warnings in the driver's cabin. With the help of a GPS antenna and computer, the combine harvester can provide a yield map of the field. Such yield maps are very useful for the site-specific soil-water-plant management, which in turn ensure improved agricultural productivity.

Combines for peas and similar crops employ some of the monitoring aids found in the grain combine, but selective harvesting methods are used for vegetable harvesting. Furthermore, potatoes, sugarbeats, onions, etc. can be sorted from stones and clods by means of an X-ray sorter. Tramp metal detector fitted in the forage harvester can avoid serious hazards to the livestock. The rate of application of preservatives to forage crops in proportion to the moisture content of the forage can also be efficiently controlled by suitable electronic systems.

Machine Performance and Tractor Testing

Microprocessor-based units can display a range of information on the performance of a machine including engine rpm, running hours, PTO speed, state of battery, forward speed, wheel slip, area and distance covered in a set time. Automatic guidance of agricultural vehicles in a structured environment or an iterative structural environment by a laser sensor is reported in Chateau et al (2000). Moreover, the self-propelled tractor load car is effectively used for testing tractors. It is fitted with modern microprocessor-based instrumentation to collect and analyze the data during the course of progressive testing.

Greenhouse Farming

The cost of infrastructures, and all services and their running costs warrant the greenhouse growers to take up new technology for greater efficiency. Automation of greenhouses is a major area of research these days in both developing and developed nations, which promises a lot for greenhouse growers of the new millennium. The application of computers to greenhouse farming is briefly described under the following two headings.

Control on the Aerial Environment of Greenhouses: The weather parameters concerning greenhouse aerial environment include sunlight, wind speed, temperature, and humidity. These parameters can be controlled by their real-time monitoring, which is possible only by means of the sensors for these parameters. The field data so obtained could be continuously sent to a PC in the manager's office, and then these data could be analyzed for efficient control of the greenhouse aerial environment. Thus, the quality and quantity of greenhouse products could be enhanced substantially on a long-term basis.

Control on Root-Zone Environment: In the commercial greenhouse, plants may be growing in soil, peat bags and other solid composts, or in nutrient solutions. Both solid and liquid media call for the regular or continuous measurement of soil moisture, temperature, EC, and pH, besides the monitoring of greenhouse aerial environment as mentioned above. For this, electronic instruments, with datalogging facilities may prove beneficial and effective. Moreover, using automated micro-irrigation systems, a high-level control on the water and fertilizer application can also be obtained. Such instruments and system will, thus, ensure efficient utilization of agricultural inputs, with improved crop yields.

Post Harvest Operations

Crop Handling

The microprocessor has found application in the equipment used for batch weighing and packing of potatoes, onions, and other vegetables. In addition, the loading on a conveyor can be determined by a solid-state TV camera, and ultimately the efficient speed control by a microprocessor.

Crop Processing

Crop cleaning and grading need continuous application of human eyes and brain. Hence, during sieving, the computer-based sensors can prove efficient to make often-subtle distinctions between the acceptable and the reject for a particular grade quality. Computer-based color sorters as well as automatic size and weight grades are available these days for seeds and vegetables. Image processing technology is playing an important role in this area. Furthermore, the protein content of grains can also be sensed electronically. The microprocessor-based monitoring and control of temperature, humidity and air flow rate ensure the most efficient operation of grain dryers.

Crop Storage

For stabilizing the condition of dried crops, heating, cooling and humidification are required to combat the frost damage, self-heating, and moisture-loss of crops. Microprocessor-based monitoring and control unit helps in monitoring the temperature of stored grains by means of a fan control box. Similarly, other storage parameters of several vegetables and fruits can be monitored automatically in real time.

Studman (2001) presents an excellent overview of the growing application of computers and other electronic devices in the above-mentioned areas of post harvest technology.

Animal Husbandry

Electronic systems help with the chores, maintain vigilance over the animal husbandry operation, and provide timely livestock management information. For instance, creation of a controlled environment for cattle and/or pig and bird raising, automated feeding and milking systems, milking robots, and the monitoring of health and special periods of animals are salient activities among several others where computers play a central role and promise a lot more. Such electronic systems are efficient, less time-consuming, and not labor-intensive. In addition, if these systems are applied judiciously, they ensure increased and sustainable animal production, which is the need of the hour. Frost et al (1997) present a review of the computer/micro-processor application in monitoring animals and their environment. They emphasize the need for developing integrated monitoring system techniques for efficient livestock management. The succeeding sub-sections briefly deal with the various activities concerning animal husbandry wherein the use of computer and other electronic systems may prove beneficial and efficient.

Monitoring and Control of Livestock Environment

There is a well-defined range of ambient temperatures within which livestock perform best and the economic advantage of establishing these conditions are substantial. The specific ambient conditions such as temperature, relative humidity, light, and ventilation can be well monitored and controlled by means of electronic sensors with datalogging facilities. The use of electronic nose to detect odour and gases is an excellent example in this direction. Moreover, the control of NH_4 (ammonia) emissions and dust in pig and poultry husbandry can be best achieved by a computerised system, which in turn will ensure eco-friendly animal husbandry.

Hatcheries

Egg hatching in incubators is a mass-production process that calls for a precise control of temperatures. It also requires a moderate degree of control over relative humidity, O_2, and CO_2 levels. Automatic weighing of the incubating eggs often provides a basis for regulating relative humidity.

Feed Monitoring and Control

Precise control of feed rations is of utmost importance because feed costs amount to 75 to 80 % of the total production costs in pig and poultry enterprises (Lecture Note, 2001). Also, regulated feeding ensures better health and growth of animals and birds. Automatic systems for conveying both dry and wet feeds are becoming popular. Water consumption by pigs and poultry needs also to be measured in order to monitor total inputs.

Weighing

The live weight gain of meat animals is also an important economic factor. Regular and rapid weighing of animals and birds provides information based on which the feeding can be regulated, which finally fetches maximum financial returns. A computerized weighing system can display a histogram together with the mean and standard deviation of the measurements.

Egg Grading

In egg grading, electronics provides a useful aid to the grading efficiency. The interior defects in eggs can be detected automatically by using suitable sensors and high-precision digital cameras. As in the vegetable and fruit grading, the electronic circuit stores the information in memory and automatically relates it to the movement of the conveyor, and finally the egg grading is accomplished very quickly and efficiently. Neural networks have been developed for the detection of blood spot, crack, and dirt strain defects in eggs (Patel et al, 1994; 1996). Patel et al (1998) have developed and evaluated an expert system for sorting eggs into pre-defined categories.

Dairy Automation and Herd Management

The most cost-effective feed proportions can be calculated with the help of computer software. Further cost reductions can be achieved by using a computer to control the performance-related feed rates for individual cows. The type and amount of feed ration dispensed to each cow can be effectively controlled.

Continuous monitoring of lactating animals' health and fertility is another important area of computer control in dairy farming (e.g., Maatje et al, 1997). For instance, thermal sensors installed in a milk collector immediately below the teat cups can provide general information about a cow's health at a very early stage, thereby alerting the farmer to check for the specific disorders such as infection in the udder or genital organs. Measurement of pH and specific constituents of milk can be accomplished by additional sensors for better milk analysis. It has been found from experiments that cows prefer to be milked four times per day --- a frequency that gives higher yields and makes cows less susceptible to udder infections. This and other such natural rhythms can be duplicated with a robotic milking system programmed according to the individual animal' s requirements. Ordoff (2001) describes the evolution of controlled milking in the world and its importance. It is concluded that automatic milking systems are very beneficial and efficient. Furthermore, the culling of a specific cow or animal from herd can be done quickly and timely by means of electronics devices.

Thus, the automation of dairy

operations can enhance the process efficiency, improve product quality, and conserve valuable resources, which in turn can ensure eco-friendly and sustainable dairy production.

Farm Planning and Management

Besides accounting and financial management by on-farm computers, the selection and replacement policy for farm equipments can also be dealt with accurately and timely. The use of CAD/CAM for the design and fabrication of agricultural machinery and/or equipment is another important area of agriculture, wherein computers play a significant and revolutionary role. The efficient and quick crop planning and farm resource management can also be accomplished with the help of computer simulation and management models. At present, varieties of computer software are used in developed nations and the cost-effective and need-based computer software are increasingly made available for the farmers of developing nations. An excellent example of useful technology is the use of Internet and the website creation. Websites may be comprised databases containing farm and personal information, chat-room opportunities and useful agricultural links. Thus, farmers can communicate and share information or views with other farmers in different parts of their own country or foreign countries. However, to utilize this technology, farmers must be able to communicate via the web and e-mail.

Moreover, owing to the complexity of agricultural management problems, reliance on experience and experts is necessary for effective decision-making. Expert systems (ES) and decision support systems (DSS) are efficient means for providing decision support to the tasks primarily requiring experience-based knowledge (e.g., Yaldir and Rehman, 2002; Lilburne et al., 1998). Although ES holds promise for various applications in agriculture, a problem addressed by an ES should be truly meaningful and the solution must be cost-effective (Kumar and Mohanti, 2000). Furthermore, opt-simulation modeling using remote sensing and GIS techniques has a promising future for efficient farm planning and management.

Aquaculture and Forestry

Continuous monitoring of the quality of water for fish growing and the growth of fishes is possible using various kinds of sensors and dataloggers. The aerators, feed preparing machines and fish processing machines can be automated for efficient and rapid aquacultural activities. Lines et al (2001) has developed and tested an image-based system for estimating the mass of swimming fish.

Forestry including the agroforestry, also offers a lot of scope for computer application. Using soil, water and weather sensors and other electronic devices as well as the use of decision support systems and experts system, efficient planning and management of forest resources can be obtained. Thus, precision forestry/agroforestry can ensure improved economical benefits and ecological sustainability. Sugumaran (2002) reports the development of an integrated range management decision support system for the planning and management of forests in the Western Ghats of India. On the other hand, Ellis et al (2000) have developed a GIS-based decision support system for agroforestry planning and tree selection in Florida State. Gustafson and Rasmussen (2002) used a timber harvest simulation model known as "HARVEST 6.0" to determine the sensitivity of landscape pattern to the interactions among three selected strategic parameters. It is concluded that HARVEST has advanced from being strictly a research tool to a strategic management planning tool.

Computer Vis-à-vis Education & Rural Development

Computers are tremendously fast and accurate to the point of being infallible. A computer can work all day and all night without a break, and does not have distracting personal problems. They relieve engineers and researchers of more and more repetitive and routine tasks, allowing them additional time for creative and analytical thoughts for solving real-world problems. High capacity and high speed computers and other electronic equipment enable the engineers and scientists to analyze the complex real-world problems efficiently using state-of-the-art techniques and emerging tools. Moreover, engineers and scientists can develop varieties of mathematical models by using a computer even without carrying out any field or laboratory experiments. Development of simulation and optimization models, DSS and ES and their use for solving real agriculture-related problems is a worldwide research activity for the past few decades. The remote sensing and GIS are emerging as useful and powerful techniques for efficient planning and management of land, water and other agricultural inputs. Modern information and communication technology provides opportunities for reaching the unreached. Computer aided and Internet connected virtual colleges/universities linking scientists/engineers and the people living in poverty (rural areas) can be established at local, national and global levels for launching a knowledge and skill revolution. To this end, an "Information Village" in Pondicherry, India is a model worth replicating. The Warana Project in the state of Maharashtra, India is another excellent effort to promote rural development by harnessing the power of information technology. This project was implemented in December 1998 and is expected to be the forerunner to many such rural development projects envisaged by the IT Task Force, Government of India (Dash, 2002).

Problem solving with the help of computers is indeed more efficient, less time-consuming and highly insightful. Therefore, the use of computers and computer software in teaching is growing fast. Courses on simulation modeling and systems optimization are finding place in modern curricula of higher degrees. However, it is worth mentioning here that computer models must not be deemed as a substitute for laboratory and/or field experiments. They are merely tools that aid to better understanding of the complex and dynamic real systems. In fact, no computer models can yield rational and useful results without reliable and good quality field and/or laboratory data.

Conclusions

It has been well recognized that information is a critical input for agricultural development. It is as important as other key inputs such as credit, seeds, nutrients and water. Information can be efficiently converted into economically rewarding opportunities. Indeed computers make our thoughts' processing more precise, planning and decision making much faster and most effective. They have taken root in everyday life and agribusiness. It can play a central role in the agriculture sector, with widespread areas of application. High tech advances have been a boon to farmers by making some aspects of farming life easier and more profitable. For instance, rapid development and adoption of new technology has made the US and European farmers the most productive in the world. These days computers are widely used for integrated pest management (IPM), plant disease management, irrigation water management, harvesting, storage and veterinary medicines. Some of the most up-to-date technology is the growing use of precision agriculture. Undoubtedly, eco-technology based precision farming can help cut costs, enhance marketable surplus and eliminate ecological risks. Developed nations are progressing fast with an increasing use of computers in agriculture. A wide variety of simulation and optimization computer models, DSS and ES are developed to help farmers take prompt and effective decisions and actions. Thus, agricultural scientists and engineers have unique opportunities for designing farming systems and optimizing resources to achieve the triple goals of more food, more income and more livelihoods per hectare of land. It is possible only when we harness the tools of eco-technologies, resulting from a blend of traditional knowledge with frontier technologies.

Though more and more basic research is required to enhance the utility of computers in the agriculture sector, even the existing potential is not fully utilized, especially in developing nations. Now, it is the time when a person without a working knowledge of computers will be at a disadvantage in performing his duties. The farmers, who are not utilizing current technology, may be left behind. An unfortunate part of new technology, however, is that it is mostly geared toward large farmers. Small-scale farmers don't have the size to utilize the technology efficiently. As cost for new systems goes down, the smaller farmers are taking advantage of them, but only to a point. They can't afford it --- it is a matter of income and economics. Nevertheless, given a sound government policy and the farmers' willingness to use advance technologies, it is hoped that judicious and advantageous uses of computers in the agriculture sector will increase in the future, even in developing countries. It is now well recognized that the use of new technologies and tools will help meet the daunting challenges ahead and will ensure long-term sustainability of agricultural production in an environmental friendly manner. While promoting advance technologies in developing countries, one should bear in mind the suggestions made by Mr. Ismail Serageldin," *Mobilizing science is not just a matter of brandishing new technologies. Together with modern technologies, we must make sure that poverty reduction remains the guiding impulse for all our nations, and that we use our resources, harness our intellect, and direct our knowledge to benefit the poor, the hungry, and the marginalized".*

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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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Current Practices in the Utilization of Groundwater for Irrigation by STWs in the Upper Pampanga River Basin: **S. M. Iqbal Hossain**, Assistant Agricultural Engineer (Gr-1), Agricultural Engineering Division, Bangladesh Sugarcane Research Institute, Ishurdi - 6620, Pabna, Bangladesh, **Honorato L. Angeles**, Professor, Dept. of Agricultural Engineering, Institute of Graduate Studies, Central Luzon State University, The Science City of Munoz, Nueva Ecija, Philippines.

The study was conducted through direct interview of shallow tube well (STWs) owners to enumerate current practices and problems in groundwater utilization for irrigation by STWs in the Upper Pampanga River Basin (UPRB). For this purpose, 100 farmers were selected and interviewed from 34 municipalities within the basin.

The results revealed that the average discharge of the STWs in the basin was found to be 10.75 lps with a range of 2.64 to 16.33 lps, withdrawing groundwater for irrigating various crops during the dry season (January to April, 2001). About 78 % of the STWs were used for irrigating rice fields while 12 % for onion and the remaining 10 % for other vegetables. The average area irrigated by one STW was found to be 2.1 ha which is less than the recommended area of 3 ha. This means that STWs are underutilized in the basin area. The average yield of rice was found to be 4,421 kg/ha while that of onion was 6,616 kg/ha.

The trend of STW establishment shows that more than 70 % of the STWs in the basin were established during 1990s. About 39 % of the engines used with STWs were Yanmar Japan brand and 35 % were of Kubota Japan brand. On the other hand, about 30 % of the pumps were of Sakai brand; 16 % of Taro and 14 % of Kato brand. About 84 % of the engines were bought second hand surplus engine.

Most of the STWs were installed near their fields. It was found that about 90 % of the STWs were installed within 10 meters from the field to be irrigated while 61 % were found to be at zero distance from the irrigated field. Due to lack of proper implementation of the existing regulations, 20 % of the STWs were installed within 20-50 meter distance from the nearest STW and 50 % were within 20-100 meters.

The findings of the study revealed that STWs of the UPRB are underutilized. The main reason for this is the lack of knowledge of the farmers about irrigation water management and proper maintenance of STWs. There are government policies to address these problems but they are not properly implemented.

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Performance Evaluation and Economic Analysis of Potato Digger: **Mohit Gupta,** B. Tech. Final Yr. Student, COAE & T, CCS HAU, Hisar - 125 004 (Haryana), India, **Sudama Aggarwal**, Professor, Department of Farm Power & Machinery, same.

Among Various crops grown in India, potato ranks first in terms of yield per unit area and ranks 4th in potato production worldwide. As potato planting and harvesting requires about 50 % and 33 % of the total labor requirement of the crop, respectively, so the mechanization for potato cultivation becomes very necessary to reduce the labor requirement, time utilization and cost. For harvesting of potato various types of potato diggers are being used partially in India, because the farmers are not having the clear picture regarding its economics and damage percentage. Keeping this in view, a study was conducted to reveal the economics and quality of works of potato diggers. The results of the study revealed that the optimum yields are with L-2 gear (3.14 kmph) and 27 cm depth, where the percentage of healthy potato yield is 98 % and the percentage of injured potato is 0.9 %. Harvesting of the potato with potato digger costs 22.32 $ per hectare whereas the manual digging costs 40.64 $. Thus it was concluded that tractor drawn potato digger is 55 % cheaper as compared to the manual digging by spade or khurpi. The tractor drawn potato digger required 107 man hrs/ha where as manual digging required 347 man hrs/ha.

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Effect of Soil Conditions on Power Performance of Primary Tillage Implements: **Ballel Zaid Moayad**, Ph. D. student, The Key Laboratory of Terrain-Machine Bionics Engineering (Ministry of Education, China), Jilin University (Nanling Campus), 142 Renmin Street, Changchun 130025, P.R. China, **Mohamad Hassan Dahab**, Professor, Department of Agricultural Engineering, Faculty of Agriculture, University of Khartoum, Sudan, **Jin Tong**, Professor, The Key Laboratory of Terrain-Machine Bionics Engineering (Ministry of Education, China), Jilin University (Nanling Campus), 142 Renmin Street, Changchun 130025, P.R. China.

The present study was conducted to investigate the effect of firm and loose condition of surface of a clay soil with extremely low moisture content on draft force, rear wheel slippage, traveling speed, drawbar power and fuel consumption rate required for disc plough, chisel plough and moldboard plough. The experimental work was carried out on the summer season in Khartoum province of Sudan. The implements were operated with a two- wheel drive tractor at the first gear. The results showed that the draft force and slippage for all ploughs in the firm condition were higher than in the loose condition, consequently the speed in the firm soil was found to be lower than in the loose one. The drawbar power for disc and moldboard in the firm soil was higher than in loose soil, while the higher power for chisel was recorded in the loose condition. Disc and chisel recorded higher rates of fuel consumption in the firm condition, while moldboard plough recorded no significant difference between the two conditions at 1 % level.

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Design, Development and Testing of an Animal Drawn Ridger for the Traditional Vegetable Farmers in Shambat Area, Sudan: **Elsamawal Khalil Makki**, Lecturer, School of Rural Extension, Education and Development, Ahfad University for Women, Omdurman, Sudan.

An animal drawn ridger was designed (**Fig. 1 a** and **b**), developed and successfully tested during the period from June 2003 to January 2004. The ridger was mainly designed to be used by the traditional vegetable farmers in Shambat Sudan. The designed ridger recorded appropriate ridge height, ridge width and distance between ridges, which resulted in superior field capacity, field efficiency, as compared to the traditional ridging process using the plough and the two-man shovel. Ridge formation costs (SD/feddan) by the designed ridger were 61 % and 46 % less than the traditional plough and two-man shovel, respectively.

487

Economic Feasibility of Straw Harvester in Wheat in Northwestern India: **K.K. Singh**, Senior Scientist (FMP), Project Directorate for Chopping Systems Research, Modipuram, Meerut - 250 110, India, **A.S. Jat**, Research Associate (Agronomy), same, **S.K. Sharma**, Project Director, same.

A study was carried out at the experimental farm of the project directorate to find out the economic feasibility of straw harvester in combine harvested wheat fields. The Dasmesh - 841 make straw harvester with unit cost of US $ 1,640 was used in fields after the wheat harvesting by Swaraj - 8100 combine. It had 2,135 mm long cutter bar and requires about 50 HP tractors. The pick-up diameter of real assembly and width of threshing drum were 457 and 1,385 mm, respectively. The operating speed was 850 rpm. The blower diameter and blower width were 635 and 200 mm, respectively. The effective width of cut and average speed of operation of the harvester were 2,135 mm and 2.2 km/h, respectively. The effective field capacity was 0.44 ha/h with field efficiency of 67 %. The average height of stubbles before and after reaping was 384 and 38 mm, respectively. The average straw split was 90.9 % whereas average length of straw ranged from 14 to 17 mm. The average straw recovery was 86.3 % (3.25 t/ha). The average weight of grains collected in the pan was 0.12 t/ha with 44.3 % recovery. The average fuel consumption was 4 l/h. The labor requirement, cost of operation and energy requirement were 4.5 h/ha, 17.3 US $/ha and 649 MJ/ha, respectively. The net return from one hectare of wheat field was US $ 88.6 and the benefit: cost ratio was 6.12. The use of straw harvester will, therefore, be a better substitute to straw burning.

534

Primary Investigation into the Performance of Animal Drawn Puddler: **Jagvir Dixit**, Assistant Professor (Agril. Engg.), Division of Agricultural Engineering, SKUAST-K, Shalimar, Srinagar - 191 121 (J & K), India, **N.C. Shahi**, Assistant Professor (Agril. Engg.) same, Intikhab Syed, Research Associate, same, **Deldan Namgial**, Research Associate, same.

A field experiment was conducted to study the performance of animal drawn puddler in respect of puddling quality (**Fig. 2**). Puddling quality was judged on the basis of puddling index, bulk density and percolation loss. It was found that by using animal drawn puddler, 84.5 percent puddling index (PI), 1.45 g/cc bulk density and 0.85 cm/day percolation loss were achieved under actual field condition, which was better than conventional method of puddling. The field capacity and field efficiency were observed 0.10 ha/h and 71.42 percent in case of puddler, which were 87 and 23 percent higher than traditional method of puddling. The cost of operation under puddler and conventional method was found Rs.182 and 1,188.23 per ha, respectively.

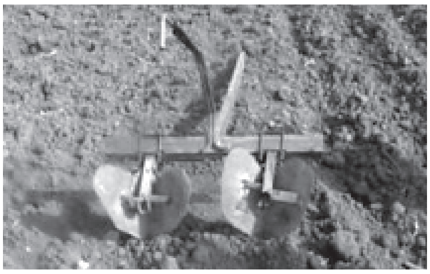

Fig. 1a The second design of the HAFEED ridger (rear view)

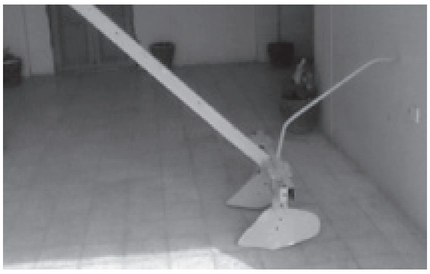

Fig. 1b The second design of the HAFEED ridger (side view)

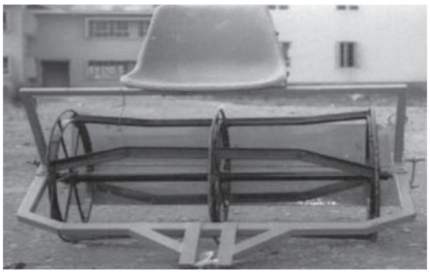

Fig. 2 Animal drawn puddler

NEWS

Massey-Ferguson Educational Award

Gajenda Singth (Vice Chancellor, Doon University, Dehradun, Uttanchal, India)

Likenesses of Daniel Massey and Harry Ferguson, co-founders of Massey-Ferguson, lnc., appear on the front of this gold medal. The other side depicts' a montage of images significant to the agricultural engineer - mathematic symbols, a farmer with a scythe and an open book. The legend on the back of the medal reads, "For Advancement of Engineering Knowledge and Practice in Agriculture."

The stated purpose of the Massey-Ferguson Educational Award is "To honor those whose dedication to the spirit of Learning and teaching in the field of agricultural engineering had advanced our agricultural knowledge and practice, and whose efforts serve as an inspiration to others."

Established in 1965, the endowed award is named for Daniel Massey, pioneer Inventor and agricultural machinery manufacturer, and Harry Ferguson, Inventor and ardent exponent of agricultural mechanization.

Gajendra Singh, ASABE Fellow, is the recipient of the 2006 Massey-Ferguson Educational Award in recognition of his outstanding dedication and contributions as a highly effective leader and teacher of agricultural engineering. He is the first individual to receive the award from outside the United States.

Singh recently assumed the position as vice chancellor of Doon University in Dehradun, Uttranchal, India. Doon University was established in April 2005. As vice chancellor, he is CEO and responsible for all matters related to management and operation of the university. Prior to this position, Singh played a key role in the establishment of agricultural engineering education at the Asian Institute of Technology. Since that program' s beginning in 1975, it has produced more than 900 master' s - and 60PhD-level agricultural engineers, who are currently working in more than 40 countries within Asia and Africa.

While serving as deputy director-general (engineering), the highest position for an agricultural engineer in the Indian Council of Agricultural Research (ICAR) in New Delhi India, Singh modernized the agricultural engineering curriculum in 24 institutions, with a collective enrollment of more than 1200 students.

As the founding president of the Asian Association of Agricultural Engineering, Singh effectively brought together agricultural engineers, various other professionals, and allied organizations to promote the profession and education. He established a professional forum for these groups and individuals through publication of an internationally recognized journal and newsletter, as well as through conferences, workshops, Seminars, training programs and exhibitions, securing the cooperation of agricultural engineering societies such as ASABE and CIGR. He has published extensively on agricultural engineering topics.

A 30-year member of ASABE, Singh has provided expertise to the International Affairs & Relations committee, Program committee, Service to International Members committee, Subsurface and Trickle Irrigation committee, and the Board of Trustees. He has received the ASABE Kishida International award and was elected a Fellow in 1998.

Singh's other awards and honors include the University of California's John Gilmore Award for Scholarship, Activities and International Understanding, and the Emil Mrak International award; Indian Society of Agricultural Engineers Gold Medal and the Commendation Medal for Outstanding Contributions in Education; and the G.B. Pant University of Agriculture and Technology Most Distinguished Alumni award. He was elected a Fellow in the CIGR, the National Academy of Agricultural Sciences of India, the Institution of Engineers (India), and the Indian Society of Agricultural engineers. He is a member and management committee member of the Ctub of Bologna. He has served as consultant to the United Nations (UNDP, FAO), Asian Development Bank, European union and CGIAR Institutes.

Innovations in Food and Bioprocess Technologies

12-14 December 2006, organized by Food Engineering and Bioprocess Technology, Asian Institute of technology, Bangkok, Thailand

Theme of the Conference

Developments and innovations in Food processing and biotechnologies.

Background

The Food Engineering and Bioprocess technology program in ATT has organized two international conferences on Innovations in Food Processing Technology and Engineering since year 2000. For the first time, this year's conference will also be incorporating the role of bioprocess technologies in the food industry.

Rationale

With the growing economy, demand for high quantity and quality foods in the Asia-Pacific region are increasing leading to a rapid growth in food processing industries to meet the needs of domestic consumption as well as export. Food safety issues, traceability, rapid detections methods and treated foods have arisen during this period, which required greater understanding of food processing operations for ensuring high quality and safety of foods. Therefore, better utilization of existing technologies and adoption of new innovative technologies would continue to demand greater attention and emphasis.

In order to address and discuss such challenges, the International Conference on Innovations in Food and Bio Process Technology is being organized by Food Engineering and Bioprocess technology at the Asian Institute of Technology, Bangkok, Thailand.

Objective

The conference is aimed to provide a forum for presentation and discussion of the current and new developments in food and bioprocess technologies along with the dissemination of relevant information among scientists, engineers, technologists and other professionals in the Asia Pacific region.

Topics
•Food processing technology
•Physical properties of foods
•Thermal/Non-thermal processing and preservation
•Food packaging
•Nutraceutical and functional foods
•Novel technologies in food handling, processing and transport
•Food and biosafety
•Bioprocessing of byproducts of the food industry
•Rapid detection methods of foods
•Product Development

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Dr. M. Shrinivas Rao

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International Conference on Agricultural Food and Biological Engineering and Post Harvest/Production Technology

21-24 january, 2007, Sofitel Raja Orchid Hotel, Khon Kaen, Thailand

The American Society of Agricultural and Biological Engineering (ASABE), in association with the Thai Society of Agricultural Engineers (TSAE) and Khon Kaen University are proud co-sponsors of the International Conference on Agricultural, Food and Biological Engineering and Post Harvest/Production Technology. We invite you and your members to participate in this international conference to be held at the Sofitel Raja Orchid Hotel in Khon Kaen, Thailand on 21-24 January 2007.

This International Conference is organized to provide an excellent opportunity for researchers, academies, professionals and entrepreneurs/practitioners in the fields of agricultural, food and biological engineering, together with Post Harvest/Production Technology from various organizations such as universities, ministries, public and private institutions as well as industrial enterprises to disseminate new knowledge and technology. The participants will meet and share experiences/visions/expectations in order to strengthen links between each other and be updated on recent progress and future perspectives in the relevant fields at international level.

The International Conference on Agricultural, Food and Biological Engineering and Post Harvest/Production Technology is currently accepted abstracts of papers, posters and products for topics such as power and machinery, soil and water, food and process engineering, biological engineering - technology and renewable energy, post harvest-production technology, information and communication technology (ICT) in agriculture, agricultural environmental management and other related areas.

For more information visit website at http://www.ae-thailand.com

International Agricultural Engineering Conference

3-6 December 2007, ATI Conference Center, Bangkok, Thailand

The main objective of this jnternational conference is to provide a forum for discussion and transfer of information and technologies on current researches, developments and practical applications of agricultural engineering and its allied fields. The theme of this conference is **" Cutting edge technologies and innovations on sustainable resources for world food sufficiency"**.

Those interested to present papers are invited to submit a 1-pade abstract (up to 500 words) which should contain, in brief, the objectives, methodology, key results and conclude in a short, straight forward 'take home message'. Posters will also be accepted for presentation and display. The deadline for receiving abstracts is on 1 March 2007. The list of selected papers will be made available by 1 June 2007.

Papers are invited in any of the following areas:
•Agricultural engineering education
•Agricultural systems
•Agricultural waste management
•Agro-industry
•Electronics in agriculture
•Ergonomics
•Food engineering and biotechnology
•Power and machinery
•Soil and water engineering
•Structures and environment
•Terramechanics
•New materials and other emerging technologies including but not limited to:

Advanced machine systems including sensors and controls; Mechatronics; Precision farming and variable rate technology; GPS and GIS technologies; bio-machine systems; Ecological engineering; Wetland designs for water quality control systems; Food safety and bio-process engineering; Food traceability and safety; Livestock building design for animal welfare and hearth; Watershed design for water quality protection; and Educational programs in biological natural resource engineering.

Program Outline: The conference is designed for four days. Three days will be allocated for oral and/or poster presentations held in plenary and parallel sessions. Technical tour is scheduled on the fourth day. Full papers will be published separately in Proceedings which will be available in electronic format.

Language: English will be the official language in this International Conference.

Important dates:
•2nd announcement/call for papers: 1 Jan2007
•Deadline for submission of abstracts: 1 Mar 2007
•Notice of acceptance: 1 Jun 2007
Full paper due: 1 Sep 2007
Early registration with payment due: 1 Oct 2007

For more information, please contact:
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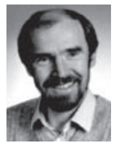
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■■

INSTRUCTIONS TO AMA CONTRIBUTORS

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

Criteria for Article Selection

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

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

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a. As a rule, articles that are not chosen for AMA publication are not returned unless the writer(s) asks for their return and are covered with adequate postage stamps. At the earliest time possible, the writer(s) is advised whether the article is rejected or accepted.
b. When an article is accepted but requires revision/modification, the details will be indicated in the return reply from the AMA Chief Editor in which case such revision/modification must be completed and returned to AMA within three months from the date of receipt from the Editorial Staff.
c. "The AMA does not pay for articles published. However, the writers are given collectively 5 free copies (one copy air-mailed and 4 copies sent by surface/sea mail) of the AMA issue wherein their articles are published. In addition, a single writer is given 25 off-prints of the article and plural writers are given 35 off-prints (also sent by surface/sea mail)"
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Procedure

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

Format/Style Guidance

a. Article must be sent on 3.5 inch floppy disk or CD-R with MS DOS format (e.g. Word Perfect, Word for DOS, Word for Windows... **Absolutely necessary TEXT FORMAT**) along with two printed copy (A4).
b. The data for graphs and the black & white photographs must be enclosed with the article.
c. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features:
(i) brief and appropriate title;
(ii) the writer(s) name, designation/title, office/organization; and mailing address;
(iii) an abstract following ii) above;
(iv) body proper (text/discussion);
(v) conclusion/recommendation; and a
(vi) bibliography
d. The printed copy must be numbered (Arabic numeral) successively at the top center whereas the disc copy pages should not be number. Tables, graphs and diagrams must likewise be numbered. Table numbers must precede table titles, e.g., "Table 1. Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Figure 1. View of the Farm Buildings".
e. **The data for the graph must also be included. (e.g. EXCEL for Windows)**
f. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
g. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
h. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
j. Convert national currencies in US dollars and use the later consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
l. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..."instead of 45 workers..., or, 5 tractors.