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EDITORIAL

Asian and Pacific Centre for Agricultural Engineering and Machinery (APCAEM), the new project of UNESCAP, had its first Session of Technical Committee and Governing Council end November last year. Asia has the world largest population and potential economic growth. Agricultural problem in Asia is the most important issue on the globe as well as for Asian countries. Whether Asian agriculture can support such enormous population is a big challenge for the people involved in agriculture.

The primary essential is to provide the technology to raise land productivity. As timely farm work is most required to increase land productivity, agricultural machines are indispensable. On seeking the most optimized work on each crop, more advanced technology such as precise agriculture is needed. It is also needed to maximize agricultural productivity by making agricultural input more practical. Mechanization of agriculture is the most important in view of optimization of agricultural input.

In most Asian countries, the population is rapidly drifting to cities from rural areas. Only cities will be densely populated while agricultural products enough to support city population are not supplied without timely dissemination of agricultural mechanization in rural areas.

In Japan after WWII, farmers purchased about 12 trillion yen worth of agricultural machines in total for 30 years during 1955 to 1985. Mechanization of agriculture allowed farmers to use their spare time working in other industries. Consequently their agricultural and industrial output was about 1,200 trillion yen in total with only one percent of investment in agricultural machines. The input to mechanization turned out highly efficient investment in economic point of view. Besides agricultural mechanization promoted the development of agriculture and other industries.

The same thing is going to happen in Asian countries. In the movement of economic globalization, Asian countries need to promote mutual exchange and cooperation. In this sense activities of APCAEM will receive much attention and expectation. Sufficient budget and effective management by the people concerned are anticipated.

I am concerned about recent trend to get rid of the term of “agriculture” in universities and many other places. It is critical issue for us involved in agriculture that “agriculture” is socially recognized and restored as the most important key word.

AMA is resolved to give continued support to mechanization of agriculture in the world with contributors and readers.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
February, 2006

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Evaluation of Solar Drying for Post Harvest Curing of Turmeric (*Curcuma longa L.*)

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Abstract

Curing of raw turmeric rhizomes, essentially boiling and drying, is very important for the development of an attractive yellow colour (mostly due to curcumin) and aroma, and the quality of the final product depends largely on the correctness of the curing (Pruthi, 1992). The effect of drying methods (direct sun drying and drying in solar dryer) on the key biochemical constituents such as curcumin, volatile oil, oleoresin and total protein of boiled turmeric (var: Erode) was studied. The quality of the turmeric rhizomes as influenced by the biochemical constituents varied at various levels of moisture content. The study indicated that the boiling and drying intensified the curcumin content, while the volatile oil, oleoresin and total protein content progressively decreased as the moisture content decreased. The results also revealed that the solar drying is better than direct sun drying as it achieved the desired moisture and essential quality in 64 hours (8 days) compared to 96 hours (12 days) in sun drying, thus saving considerable time (32 hours). Hence, the solar drying can be adopted for turmeric drying.

Introduction

Turmeric (*Curcuma longa L.*) is an important spice, which is widely used in curry preparations for its characteristic yellow colour and flavour. It is also used in cotton textiles as a colouring agent, in confectionery, in food industry, and in the preparation of medicines and cosmetics, thus having a high commercial value (Satyanarayana and Sukumaran, 1999). It is grown in tropical countries like India, Pakistan, Myanmar, Chile, Peru, El Salvador, Japan, China, Sri Lanka, Bangladesh, Indonesia, Taiwan, Jamaica, Thailand and West Indies. India accounts for 80 % of the global output. In India, during 1996 to 1997, the area under the crop was 135,000 ha and the total production was 529,000 tonnes of turmeric (Vikas Singhal, 1999).

The ethno botanical significance of turmeric can be attributed to its key biochemical constituents; namely, the volatile oil, oleoresin and curcumin. The quality of the final product is determined by the levels of these ingredients in the rhizomes. This study had the objective of assessing the effect of drying in a solar dryer on the bio-chemical constituents of turmeric.

Materials and Methods

Long turmeric fingers of the Erode variety with a moisture content of 70.24 % (w.b.) were used for this study. After harvesting, the raw rhizomes were cleaned well and the finger rhizome samples used for various analyses were taken in triplicate by separating them from the mother rhizomes. The raw samples, weighing 300 kg, were boiled in 0.10 % alkaline (sodium bicarbonate) water (rhizome: water = 1 kg: 0.3 litre)

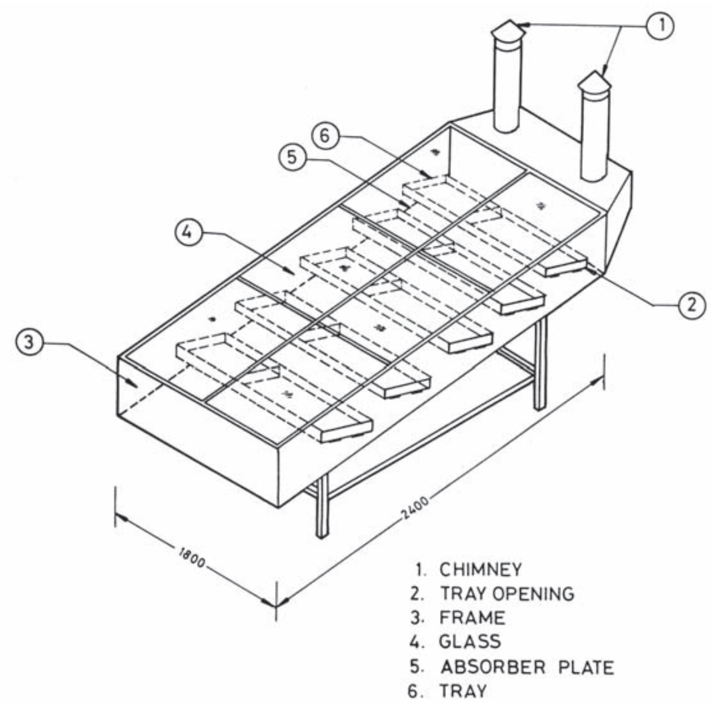

Fig. 1 Solar drier (step type)

at a temperature of 90 ºC for about 40 minutes, until frothing occurred and white fumes appeared and emitted a characteristic turmeric odour. The boiling was carried out in a mild steel pan and dried turmeric leaves were used to cover the mouth of the pan (Kachru and Srivastava, 1991). After boiling, the turmeric was drained and cooled before being used for drying and biochemical analysis. The analysis was conducted in three replications. Each replication contained the boiled turmeric rhizomes divided into four equal parts (25 kg each) after taking samples for determining the initial moisture, curcumin, volatile oil, oleoresin and protein content. Two parts were used for direct sun drying tests and the other two parts were used for the solar drying tests. Of the two parts used for each sun and solar drying, one part was used for biochemical and the other part was used for the drying studies.

The drying was carried out under direct sun and in the solar dryer after keeping the samples in aluminium trays. Solar drying was done in a popular natural draft step type dryer (**Fig. 1**) having provision to control the flow of incoming cool air while the sun drying was carried out in a clear non-shadowed area. The drying was done from 8 AM to 4 PM in a dry weather period. The sample weights were recorded daily at 4 PM and subsequently analyzed for moisture content and biochemical constituents. Temperature and relative humidity of the ambient air and hot air in the solar dryer were recorded in one hour intervals. The samples were dried until the moisture level in the samples was reduced to a safe storage level of 7 % (w.b.).

Standard methodologies have been adopted to determine moisture content, curcumin, total volatile oil, total protein and oleoresin. **Table 1** indicates the methodology adopted for the analysis.

Results and Discussion

Temperature and relative humidity of ambient air varied from 29 to 40.5 ºC and 66 to 49 %, respectively, during the study period. The temperature and relative humidity of the hot air in the solar drier varied from 30 to 70 ºC and 64 to 34 % respectively. In both the cases an increase in temperature reduced the relative humidity of air. The air temperature increased up to 1:00 PM for all the days and then reduced. Every evening the turmeric samples were packed air tight and kept at 10 ºC in a controlled atmospheric chamber. It took 96 hours (12 days) and 64 hours (8 days) in sun drying and solar drying, respectively, to get the turmeric rhizomes at around 7 % (w.b.) moisture content. An assessment of the chemical qualities of the sun-dried and solar dried turmeric was carried out and the results of the studies tabulated in **Table 2**.

Particulars	Methodology
Moisture content	ASTA method 2.0, 1997
Curcumin	ASTA method 18.0, 1968
Total volatile oil	ASTA method 5.0, 1997
Total protein	Lowry. et. al, 1951
Oleoresin	ASTA method 4.0, 1975

Table 1 Methodology adopted for the analysis

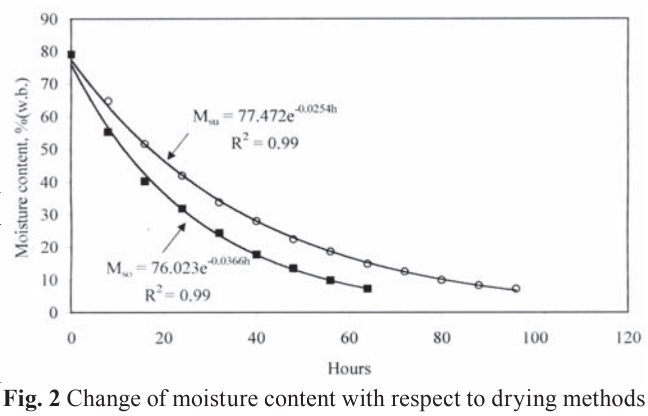

Fig. 2 Change of moisture content with respect to drying methods

Days	Hours	Sun dried, %					Solar dried, %				
		Moisture content	Curcumin	Volatile oil	Oleoresin	Protein	Moisture content	Curcumin	Volatile oil	Oleoresin	Protein
0	0	79.04	2.89	6.00	9.86	1.28	79.04	2.89	6.00	9.86	1.28
1	8	64.79	2.95	5.95	9.80	1.18	55.27	2.92	5.85	9.81	1.24
2	16	51.62	3.04	5.84	9.75	1.10	40.18	3.10	5.70	9.70	1.22
3	24	41.88	3.20	5.76	9.66	1.02	31.79	3.28	5.63	9.63	1.19
4	32	33.72	3.39	5.66	9.56	0.96	24.25	3.48	5.52	9.54	1.18
5	40	27.94	3.60	5.60	9.48	0.92	17.65	3.82	5.41	9.44	1.16
6	48	22.34	3.85	5.53	9.39	0.87	13.46	4.00	5.28	9.37	1.15
7	56	18.63	3.96	5.47	9.29	0.86	9.80	4.22	5.25	9.27	1.15
8	64	14.87	4.09	5.42	9.23	0.84	7.20	4.40	5.20	9.22	1.14
9	72	12.43	4.24	5.37	9.14	0.82					
10	80	9.86	4.31	5.33	9.08	0.81					
11	88	8.29	4.44	5.30	9.04	0.79					
12	96	7.15	4.56	5.26	8.98	0.78					

Table 2 Effect of sun and solar drying on the quality of boiled turmeric rhizomes

Effect on Moisture

The moisture content of boiled rhizomes was reduced from 79.04 to 7.15 % (w.b.) within 96 hours (12 days) in sun drying method where as it took only 64 hours (8 days) to dry the material to 7.20 % (w.b.) in solar drying method (**Table 2**). The drying of rhizomes in both the methods followed an exponential model (**Fig. 2**). The mathematical models and the corresponding R^2 values are given in equations 1 and 2 as below.

$M_{su} = 77.472\ e^{-0.0254h}$ (R^2= 0.99)....(1)

$M_{so} = 76.023\ e^{-0.0366h}$ (R^2= 0.99)...(2)

Where,

M_{su} = moisture content of sun dried turmeric rhizomes, % (w.b.)

M_{so} = moisture content of solar dried turmeric rhizomes, % (w.b.)

h = drying hours, number

The maximum temperature difference in the solar drying was higher by 30 ºC as compared to sun drying and the maximum relative humidity difference was less by 15 %. Thus, solar drying was a faster and better method for drying turmeric as compared to sun drying.

Effect on Curcumin

The initial curcumin content of the boiled rhizomes was 2.89 g per 100 g of sample at 79.04 % (w.b.) moisture level (**Table 2**). A plot of daily moisture content (w.b.) values against the corresponding curcumin values (**Fig. 3**) shows a non-linear increase in curcumin values as moisture content (w.b.) decreased in both sun dried and solar dried samples. The curcumin content increased from 2.89 to 4.56 and 4.4 g/100 g of sample in sun dried and solar dried samples, respectively. It clearly shows that there is only a small difference in the curcumin content of turmeric rhizomes dried in both the methods.

A relationship was developed between curcumin content and moisture content for both sun (Equation 3) and solar drying (Equation 4) as given below.

$Cur_{su} = 0.0004\ m^2 - 0.057\ m + 4.8821$ (R^2= 0.99).................................... (3)

$Cur_{so} = 0.0005\ m^2 - 0.0611\ m + 4.7588$ (R^2= 0.99)....................................(4)

Where,

Cur_{su} = curcumin content of sun dried turmeric rhizomes, g/100g of sample

Cur_{so}= curcumin content of solar dried turmeric rhizomes, g/100g of sample

m = moisture content of the sample, % (w.b.)

Curing of the turmeric devel-

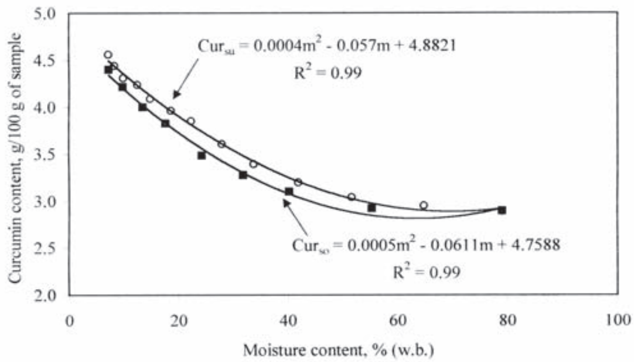

Fig. 3 Effect of drying methods on curcumin content

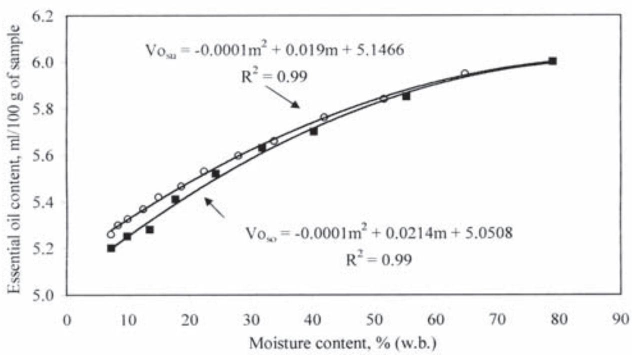

Fig. 4 Effect of drying methods on volatile oil content

oped, a yellow colour, mostly due to curcumin, as mentioned by Pruthi (1992) and Kachru and Srivastava (1991). Alkalinity of the boiling water also helped in imparting an orange yellow tinge to the core of turmeric as reported by Anonymous (1991).

Effect on Volatile Oil

The initial total volatile oil content of turmeric rhizomes was 6.0 ml/100 g of sample (**Table 2**) which decreased non-linearly during the drying operation (**Fig. 4**) from 6.0 to 5.26 and 5.20 ml/100 g of sample in sun dried and solar dried samples, respectively. There is only a very small variation in the volatile oil content of turmeric rhizomes dried by both methods. The relationships between volatile oil and moisture content for both the sun and solar drying methods is given in equations 5 and 6, respectively.

$Vo_{su} = -\,0.0001\ m^2 + 0.019\ m + 5.1466$ ($R^2 = 0.99$)......................................(5)

$Vo_{so} = -\,0.0001\ m^2 + 0.0214\ m + 5.0508$ ($R^2 = 0.99$)......................................(6)

Where,

Vo_{su} = volatile oil of sun dried turmeric rhizomes, ml/100g of sample

Vo_{so} = volatile oil of solar dried turmeric rhizomes, ml/100g of sample

Decrease in volatile oil content during curing was also reported by Joseph Philip and Sethumadhavan (1980).

Effect on Oleoresin

Boiled turmeric rhizomes had an initial oleoresin content of 9.86 g/100 g of sample (**Table 2**) which decreased non-linearly during the drying operation (**Fig. 5**) from 9.8 to 8.98 and 9.22 g/100 g of sample in sun dried and solar dried samples, respectively. The final oleoresin content in solar dried sample was higher than the sun dried sample. The relationships between oleoresin content and moisture content are shown in equations 7 and 8 for sun drying and solar drying, respectively.

$Ol_{su} = -0.0002\ m^2 + 0.0286\ m + 8.8218$ ($R^2 = 0.99$)....................................(7)

$Ol_{so} = -0.0002\ m^2 + 0.0217\ m + 9.0882$ ($R^2 = 0.99$)....................................(8)

Where,

Ol_{su} = oleoresin content of sun dried turmeric rhizomes, g/100 g of sample

Ol_{so} = oleoresin content of solar dried turmeric rhizomes, g/100 g of sample

m = moisture content of the sample, % (w.b.).

Previous studies indicate that the oleoresin consists of the volatile essential oil and non-volatile resinous fraction comprising heat components, fixatives, natural antioxidants, and pigments (Balakrishanan, 1991). It was observed that curing decreased the oleoresin content of turmeric while it improved the colour and physical appearance. Such reduction in oleoresin content in drying was also reported by Philip and Sethumadhavan (1980).

Effect on Protein

Boiled turmeric rhizomes had an initial protein content of 1.28 g/100 g of sample (**Table 2**) which decreased linearly during drying (**Fig. 6**) from 1.28 to 0.78 and 1.14 g/100 g of sample in sun dried and solar dried samples, respectively. The final protein content in the solar dried sample was high compared to the sun dried sample. The linear relationship between protein and moisture content is shown in equations 9 and 10.

$Pr_{su} = 0.007\ m + 0.7304$ ($R^2 = 0.99$)......................................(9)

$Pr_{so} = 0.0019\ m + 1.1301$ ($R^2 = 0.99$)....................................(10)

Where,

Pr_{su} = protein content of sun dried turmeric rhizomes, g/100 g of sample

Pr_{so} = protein content of solar dried turmeric rhizomes, g/100 g of sample

m = moisture content of the sample, % (w.b.)

Comparing the results obtained in this study with the prescribed index, it can be said that the levels of curcumin, volatile oils, oleoresin and protein fall within the specified requirements (Hart and Fishers, 1971) and, hence, the product is satisfactory for application and consumption. It is also observed that drying of boiled turmeric in the solar dryer was faster and saved considerable time over sun drying with only a

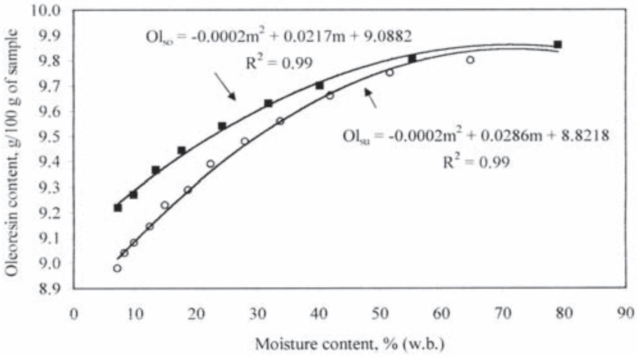

Fig. 5 Effect of drying methods on oleoresin content

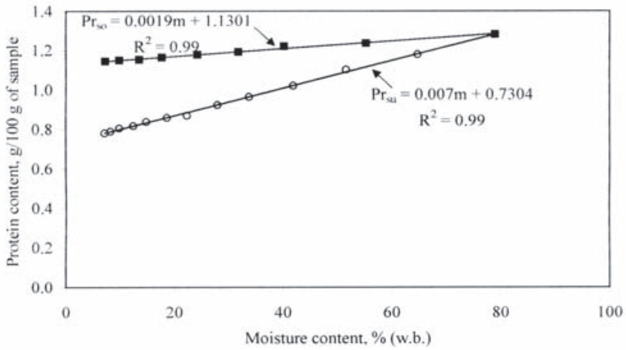

Fig. 6 Effect of drying methods on protein content

small effect on quality.

Conclusions

The results obtained in this study indicate the levels of curcumin, volatile oils, oleoresin and protein fall within the specified requirements and hence the product is fit enough for application and consumption. The solar dried product showed a greater protein content and hence it is a biologically and therapeutically better product. Although, the higher temperature in solar drying caused a slight loss of curcumin and volatile oil, the product will still satisfy the specified requirements. Furthermore, solar drying achieved the safe moisture content of 7.2 % (w.b.) within 64 hours (8 days) as against 96 hours (12 days) in case of sun drying, thus, saving 32 hours (4 days) of drying time. Hence, the solar drying method is the best possible option when compared to sun drying.

List of Notation

Cur_{so} = curcumin content of solar dried turmeric rhizomes, g/100g of sample
Cur_{su} = curcumin content of sun dried turmeric rhizomes, g/100g of sample
Vo_{so} = volatile oil of solar dried turmeric rhizomes, ml/100g of sample
Vo_{su} = volatile oil of sun dried turmeric rhizomes, ml/100g of sample
h = drying hours, number
m = moisture content of the sample, % (w.b.)
M_{so} = moisture content of solar dried turmeric rhizomes, % (w.b.)
M_{su} = moisture content of sun dried turmeric rhizomes, % (w.b.)
Ol_{so} = oleoresin content of solar dried turmeric rhizomes, g/100 g of sample
Ol_{su} = oleoresin content of sun dried turmeric rhizomes, g/100 g of sample
Pr_{so} = protein content of solar dried turmeric rhizomes, g/100 g of sample
Pr_{su} = protein content of sun dried turmeric rhizomes, g/100 g of sample
w.b. = wet basis

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■■

Front Wheel Drive Effect on the Performance of the Agricultural Tractor

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Abstract

The performance of a rear wheel drive and a front wheel assist tractors was determined under identical operating conditions. Both tractors were of the same model and trademark. The tractors were instrumented in order to determine the drawbar pull and travel speed on stubble soil and fresh ploughed soil. The two wheel drive (TWD) was tested with a 3-leg subsoiler (1.45 m working width) and the front wheel assist (FWA) with a 5-leg subsoiler (2.25 m working width). Fuel consumption, field capacity and turning time were determined in plots of 0.5 ha, with a 5 m headland for turning. Soil physical and mechanical properties were measured. The instrumentation indicated that on average the FWA pulls 18 kN while the TWD pulls 15 kN in stubble soil and 16.5 kN against 13 kN on ploughed soil respectively. Drawbar power was identical on both tractors, because the TWD travelled faster but at lower pull. On tilled soil, fuel consumption (l h^{-1}) was nearly the same on both tractors and it increased by 14 % on stubble condition. In field capacity (ha h^{-1}), the FWA was 22 % superior to the TWD, and it increased over 3 % under ploughed soil condition. The FWA spent 10.7 % more time for turning. The soil condition did not affect the turning time.

Introduction

The rear axle is the driving axle of the traditional tractor concept, with two big rear and two small front wheels (TWD). The front wheels of a front wheel assist tractor are smaller than the rear wheels. The front wheels are driven through a mechanical or hydraulic transmission which can be turned on or off from the operator's work station. In Mexico, the market for four wheel drive tractors is slowly increasing. Additional to the extra purchase, price farmers do not know exactly the real field performance of these new machines, therefore, it contributes to its low acceptance. It is important to provide information to farmers required for a purchase decision. This data must be obtained through controlled field tests and compared with the results obtained worldwide.

In order to maintain a steady draught force, it is required that the largest dynamic load over the rear axle be provided within the safety support of the wheels. This dynamic load is produced by the implement weight and during operation there is a weight transfer from the front axle to the rear. On the front wheel assist tractors (FWA) the whole weight is used to generate traction force. The static weight distribution on both axles is normally distributed as 45/55 (front axle/rear axle) in order to obtain the best tractive performance (De Souza et al., 1995).

Engine fuel efficiency is defined as the ratio fuel consumption to power output. Engine speed affects power output, daily fuel consumption, specific fuel consumption and engine life. The parameters that affect the wheel traction are: wheelslip, draught, weight on the traction axle, size and number of wheels on the traction axle, and soil type. Tractive efficiency is a measure through which the traction element transforms the torque acting over the axle on a horizontal drawbar pull.

According to Bashford et al. (1985) it is necessary to consider the following to compute the optimum amount of ballast: (a) tractor configuration and dimensions, (b) implement weight transfer, (c) travel speed, (d) type of ballast, and (e) the permissible load on the traction and steering wheels. On the other hand, Pearce (1986) found, on an instrumented tractor operating with an implement, that the best performance was a lower wheelslip with FWA having a value of 13 %, as compared 28 % with TWD under the same load. It resulted in 0.9 ha h^{-1} against 0.79 ha h^{-1}, respectively.

Kucera et al. (1985) analysed the effect of the number of wheels on the drive axle of a FWA. They reported that, on stubble untilled ground, a tractor with single rear wheels was more efficient on fuel consumption than one with dual rear wheels. On the other hand, Bashford et al. (1987) found that on a FWA there were not significant differences, with ($p \geq 0.05$), on the tractive performance when dual or single wheels were used on the rear axle. They concluded that, only for giving flotation or for supporting an additional load on the axle, can it be viable economically to use dual wheels.

Ortiz (1997) reported a comparison of a FWA tractor against a TWD tractor. At the same travel speed and nearly the same engine speed, the FWA achieved, on average, a field capacity 9 to 10 % higher than the TWD at the same load. Wheelslip was lower for the FWA which and achieved 50 to 55 % more draught force. Bashford (1985) reported similar results by comparing the performance of both traction modes on a unique tractor. Paul et al. (1989), showed that the tractive effort developed by a FWA tractor increased by 50 % and that the price of this tractor is approximately 20 % higher than the TWD.

This study was undertaken to investigate the field performance achieved from the front wheel drive assist by comparing two instrumented tractors on field trials under similar working conditions, in order to establish their operating advantages and disadvantages.

Materials and Methods

This experiment was undertaken on a field of 0.5 ha. For turning at the headlands, a space of 5 m was left. The experiment had a random design. The main parameters were type of traction (two wheel drive and four wheel drive) and ground condition (stubble and tilled soil).

The tested tractors were from Ford-New Holland and their specifications are showed in **Table 1**. The implement used for the trials was a tractor mounted Category II subsoiler with depth control wheels. The number of legs can be changed on the frame, each one having spacings of 600 mm among them. The legs are inclined forward and the frame has a "V" configuration. Both tractors were instrumented by using a dynamometer and a trailing wheel for measuring draught forces and tractor speed.

The three-point hitch dynamometer has been described by Sánchez (1999). It consisted of three independent gauged transducers (**Fig. 1**) and a device for measuring the operating angle of upper link. A trailing wheel was used for determining the travel speed (**Fig. 2**). **Figure 3** shows the complete data acquisition system. The recording and storing device was a Campbell Scientific 21X datalogger. Each data point was recorded every 0.8 seg on each run.

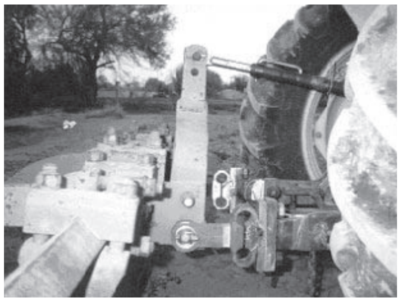

Fig. 1 Three-point linkage dynamometer

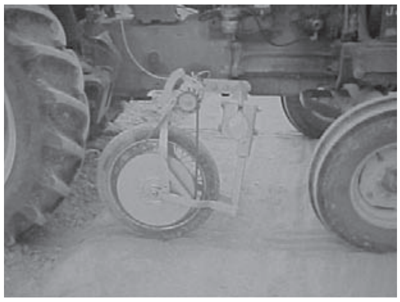

Fig. 2 Trailing wheel for measuring tractor travel speed

Specification	FORD 7610 (TWD)	FORD 7610 (FWD)
Manufacture	Domestic	Brazil
Purchase year (hours of usage)	1994 (3540)	1993 (4052)
Minimum turning radius (m)	3.59	4.11
Shipping weight (kg)	2622	2972
Weight with ballast (kg)	4180	5100
Weight ratio (front/rear)	33/67	45/55
Weight difference (kg, %)	-920 (100)	+920 (122)
Front tyres	10.00-16	14.9-24
Tyre inflation pressure (psi)	24	22
Rear tyres	18.4-34	18.4-34
Tyre inflation pressure (psi)	16	16
Transmission	8 x 2	16 x 4
Maximum power (SAE J: 1349)(kw)	77	77
Maximum torque at 1400 rpm (Nm)	306	306
Rated engine speed (rpm)	2100	2100

Table 1 Specifications of tested tractors for this research

In order to determine precisely the fuel consumption, time for field work per hectare and turning time (%), the land was tilled by controlling the following: same operator, pattern of job undertaken, area for turning, engine speed, implement depth, sensibility of hydraulic system, ballast, density of fuel, braking for turning, schedule time, land slope and optimum wheelslip. Fuel consumption was measured once the job was finished at the end of the day. Total working time was registered with a chronometer from the beginning until the subsoiling operation ended. Time for turning in the field was registered each time the implement was raised and lowered out from the turning area.

Murillo (1985), describes an economic analysis which was considered adequate for application to in this work. The purchase price for the tractors on March, 1999 were: TWD \$ 21,000.00 USD, and the FWA \$ 24,000.00 USD. The difference is obviously due to the front wheel drive option. The price of fuel was \$ 0.363 USD per litre, the operator's wages per hour \$ 0.125 USD, and the investment rate was 27 %.

Results and Discussion

Stubble conditions

The average soil physical conditions at a depth of 450 mm were: texture of sandy clay, a cone index of 1338 kPa, moisture of 20.5 % and apparent density of 3.35 g cm^{-3}.

Figure 4 shows that the implement pulled by the FWA experienced higher draught force values. This is so because it operated with a wider implement. These values are in good agreement with those found by Bashford et al. (1985). The average drawbar power was practically equal, as the TWD travelled at higher field speed.

Tilled Soil

The average soil physical properties at a depth of 450 mm were: cone index of 882 kPa, moisture of 26% and apparent density of 2.3 g cm^{-3}.

Figure 5 shows that the drawbar pull required by the implement was very steady for the TWD, which could be resulting from the fact that it pulled a 3 leg implement, achieving an average value of 13 kN while the FWA had an average value of 16.5 kN. These forces increased on the stubble condition. Likewise, the average drawbar power was slightly higher for the FWA. This is so because it had a higher efficiency under average tractive conditions and because it pulled a wider implement, but slower.

Fuel Consumption (l h^{-1})

The parameter l h^{-1} (**Table 2**) did not show significant differences between treatments with ($p \leq 0.05$). This was due to the fact that the engines were working at the same load because of the good selection of implements, gear, and operating engine speeds. On stubble ground, there was an increase of fuel consumption because ground resistance was higher. The treatments with higher consumption were on stubble condition for both types of traction devices. On tilled soil fuel consumption decreased on both tractors.

Fuel consumption (l ha^{-1}). The best treatment for this parameter was for the FWA with an average consumption of 13.76 l ha^{-1} (**Table 2**). The TWD consumed on average 3.59 l ha^{-1} more because it travelled at higher speed and with a higher wheelslip, and because it had to perform more turns since the implement was narrower. Fuel consumption per hectare was higher on stubble ground. The highest fuel consumption was observed with the TWD on stubble ground. The TWD on tilled land and FWA on stubble had no significant differences. The treatment with FWA on tilled ground was the most economical due to its additional traction.

Field Capacity (ha h^{-1})

FWA achieved better results for field capacity (**Table 3**). It achieved, on average, 0.742 ha h^{-1} while the TWD achieved only 0.596 ha h^{-1} on tilled land. This difference was because the FWA covered more land by using a wide implement (2.25 m) and by selecting the 3th power gear. The TWD had a working width of 1.46 m and used the 3th direct gear. Thus, the FWA run along the field increased by 30 %. The travel speed of the FWA was slower because the implement had the greater number of legs. The TWD could not move the subsoiler with 5 legs under the tested conditions. Traction along the surface had an influence on the parameter ha h^{-1} where the best performance was obtained on the stubble condition. The best treatment for this parameter was the FWA on stubble and tilled soil, while the TWD had better performance on tilled soil, but always less field capacity than the front wheel assist tractor.

Turning Time (%)

The TWD showed a great advantage, because its turning time was 13.2 % and 13.8 % against 15.0 % and 15.2 % for the FWA, on stubble and tilled soil respectively. The front

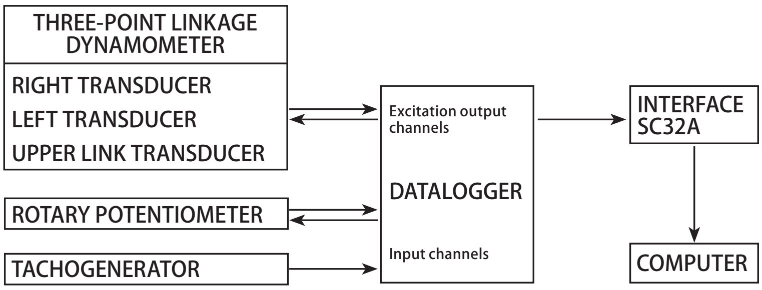

Fig. 3 Complete data acquisition system

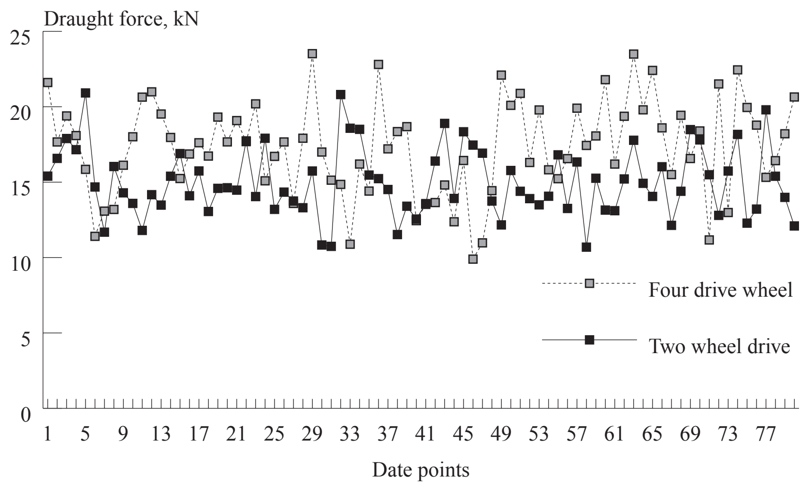

Fig. 4 Measurements of draught force on a two wheel drive and a four wheel drive tractor operating on stubble condition

Tractor	Soil condition	Fuel consumption	
		L/h	L/ha
Two wheel drive	Stubble	10.815	19.622
Two wheel drive	Tilled	8.940	15.000
Front wheel assist	Stubble	10.790	14.531
Front wheel assist	Tilled	9.633	12.995

Table 2 Average values of fuel consumption (litres/hour and litres/hectare) from both tractors on two soil conditions

Tractor	Soil condition	Field capacity (ha/h)	Turning time (%)
Two wheel drive	Stubble	0.5510	0.1320
Two wheel drive	Tilled	0.5963	0.1381
Front wheel assist	Stubble	0.7426	0.1502
Front wheel assist	Tilled	0.7415	0.1523

Table 3 Average values of field capacity and turning time from both tractors on two soil conditions

drive option reduced the efficiency of field turning (**Table 3**). It is shown that turning on the field and ground conditions did not affect these results.

Operating Costs

The capital and operating costs per hour of ownership for a FWA are higher than for the TWD. However, considering the same annual usage, the high field capacity (ha/h) and less fuel consumption of the FWA can reduce its costs per hectare compared to the TWD. Under the same analysis in this work, both tractors achieved the same operating cost per hectare only when the FWA had an annual usage of 600 hours and the TWD 800 hours.

Conclusions

The following conclusions can be drawn from this work:

Data obtained from the instrumentation was adequate and precise.

Draught power was almost equal on both tractors. The two wheel drive tractor travelled faster but draught was low while the front wheel assist tractor ran slower and its draught was higher.

The front wheel assist tractor had less fuel consumption (l ha^{-1}) than the two wheel drive on both soil conditions. Both tractors showed higher consumption on stubble condition.

The front wheel assist tractor had better field capacity than the two wheel drive tractor on both soil conditions.

The turning time (%) for the two wheel drive tractor was lower than the front wheel assist tractor. Ground condition did not affect the turning time.

Acquiring a front wheel assist tractor for subsoiling work with an annual usage of less than 600 hours per year is not economical.

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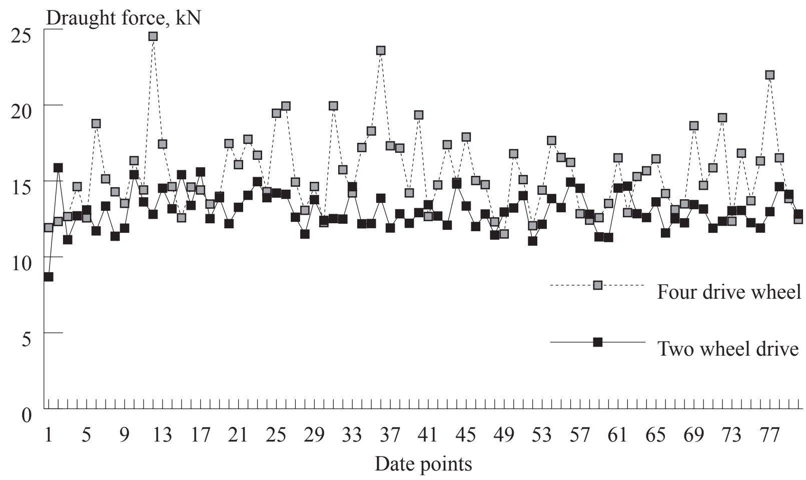

Fig. 5 Measurements of draught force on a two wheel drive and a four wheel drive tractor operating on tilled soil condition

Development and Performance Evaluation of a Test Rig for Mechanical Metering of Sunflower Seeds

by

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Abstract

A test rig with provision to accommodate various seed metering units for mechanical metering of sunflower seeds was developed. These seed metering units were mounted in the hoppers with an angle of repose equal to that in original drills. Four seed metering rollers were evaluated for regularity of seed spacing of sunflower at four different speeds of 4.11, 7.97, 11.84 and 16.04 m/min. A speed of 7.97 to 9.66 m/min. was found suitable for mechanical metering of sunflower seed. A uniformly shaped cell type (triangular small cell) with aluminum casting having 8 cells on its periphery was found suitable.

Introduction

Sunflower is one of the important oil seed crops of India that ranks next to groundnut in oil content. It is grown over an estimated area of 2.2 million hectares with an average yield of 0.68 metric tonnes/ha (Jadhav et al., 1997). Sunflower is a photo-insensitive crop, yet, it has become an important crop in North India as it fits very well in the existing cropping pattern. At present, all the operations except primary tillage in the cultivation of sunflower crop are done with traditional tools and implements which are very inefficient, labour intensive, and cumbersome to operate. Broadcasting and dibbling on ridges are the primary methods particularly used by small and marginal farmers for sowing of sunflower seeds. Broadcasting makes weeding very difficult and dibbling needs a large number of workers which are often usually not available at the peak of the sowing season. Proper placement of seeds in rows is one of the important factors in crop production that can affect crop growth and yield. Uniformity of seeds in the row depends on the performance of a metering device for a drill. Therefore, the proper design of a metering device is an essential element for satisfactory performance of a seed drill. To cope up with these problems, several types of planters/drills viz., manually operated, animal drawn, and tractor-operated machines, have been developed and evaluated in India and abroad. But, these have not become popular due to different cultural practices. Keeping in view the simplicity of this method, a test rig was developed at the college of Agricultural Engr. & Tech., CCSHAU, Hisar (India) to evaluate different seed metering device for sunflower seeds.

Description of the Test Rig

The rig frame 455 x 265 mm size was fabricated by using 30 x 30 x 3 mm size MS angle iron (**Fig. 1**). The shape of the frame was like a box with a vertical height of 915 mm. A seed hopper especially designed and fabricated from G. I. sheet to accommodate the test rollers was fitted on top of the rectangular frame. The lower portion of the box was made conical with an adjustable hopper opening and, below its conical part in the sidewalls, circular openings equal to diameter of seed roller were provided for fitting the metering roller. The roller was mounted on a 15 cm mild steel shaft supported at the both ends by M.S. bushings on the top of the main frame. The seed delivering funnel behind the hopper was divided into circular openings by conduit pipe for collection of metered seed by separate set of seed metering rollers. A reduction gear with a ratio of 20:1 was mounted on the lower portion of the frame to reduce the speed of the 1440 rpm, 0.5 kW electric motor that was fitted on the base of the frame. Several sizes of V-belt pulleys were provided for the reduction gear shaft and the seed metering shaft. An idler pulley maintained the belt tension.

Variables and Their Measurement

The variables of the study were grouped into two categories namely crop and machine variables. The effect of all the variables, along with their interactions, on the metering characteristics of the various types of seed metering rollers were evaluated to determine the optimum parameters.

Crop Variables

The functional performance of a seeding device largely depends on crop variety, shape and size, bulk density and moisture content.

(a) Crop Variety

Sunflower seed of two identified varieties of sunflower for Haryana region namely, MYCO-8 (M.S. FH-8) hybrid variety and HS-1, a composite variety, were used in all experiments.

(b) Seed Dimensions

The dimensions of the seed for both the varieties were measured with a vernier caliper. A minimum of 20 seeds were taken for each variety and average characteristic dimensions of length, breadth and thickness were calculated.

(c) Bulk Density

The bulk density of seed was measured by using a cylindrical beaker having a fixed volume 90.03 cm^3. A minimum of ten replications was taken for each variety.

(d) Seed Moisture Content

Moisture content of various seed samples of respective varieties was determined by using the hot air oven method.

Machine Variables

(a) Hopper Dimensions

Design of the hopper (size, slope of side walls, and hopper bottom openings) has a significant effect on the performance of the metering unit. It should provide free flow of seed to the metering unit with minimum damage. A rectangular hopper (27.9 x 16.5 x 22.8 cm) made from M.S. sheet with appropriate side slopes and adjustable bottom opening with holding capacity of one-kilogram of seed, was fabricated. It was fitted on the test rig to evaluate the performance of different seed metering rollers.

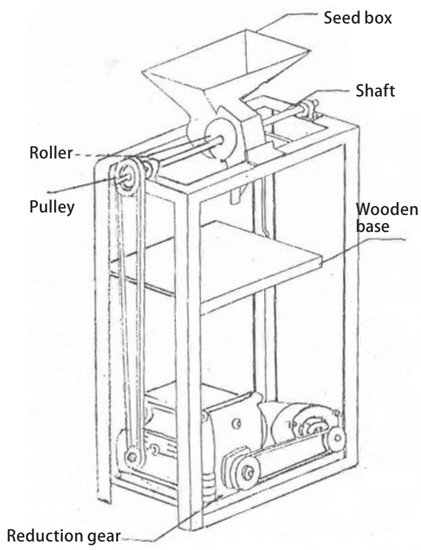

Fig. 1 Experimental test rig

(b) Seed Column Height in Hopper

According to the Bureau of Indian Standards, there should be minimum variation in the seed rates in relation to heights of seed column in the box. This can be achieved through proper design of hopper bottom. Therefore, in the present study, the seed column height in hopper was kept to the three positions of 5, 10 and 15 cm in both the varieties

(c) Seed Metering Rollers

The uniformity of plant stand in the field will depend on the metering quality of seed rollers. The seed metering roller is the most critical component for metering the required quantity of seed accurately and uniformly with minimum seed damage. Accordingly, four different rollers (**Fig. 2**) were fabricated from teak wood and aluminum casting which could be easily fitted in the seed hopper of the test rig. The rollers differed with respect to size and shape of cells on their periphery and these details are given below in **Table 1**.

Roller identity	Type of roller	Material of construction	Number of cells	Cell dimensions		
				Length/ dia (mm)	Width (mm)	Depth (mm)
R_1	Rectangular with slope	Teak wood	8	18	12	6
R_2	Circular	Teak wood	8	17	-	7.5
R_3	Uniformly shaped cell type (triangular large cell)	Aluminum casting	8	25	15	6
R_4	Uniformly shaped cell type (triangular small cell)	Aluminum casting	8	20	14	4.5

Table 1 Detailed specifications of seed metering rollers

The performance evaluation of the above four seed metering rollers was carried out on a test rig specifically developed and fabricated. The rollers were tested in both the varieties of sunflower at four different speeds. The roller speeds were varied by changing the size of the pulleys. The uniformity of seed metering in terms of seed rate, percent cell fill, seed germination, and seed damage were compared for each roller.

(d) Speed of Rollers

The peripheral speed of the metering roller has considerable effect on the uniformity of seed metering. For each vertical cell type metering roller, there is an optimum speed which gives the best uniformity of seed and minimum seed damage. The following four speeds were selected for this experiment.

	Peripheral speed (m/min)	Rotational speed (RPM)
V_1	4.11	17
V_2	7.97	35
V_3	11.84	46
V_4	16.04	70

The different rotational speeds were obtained by changing the sets of pulley in the test rig.

Performance Parameters of Seed Metering Rollers

The working performance of the four different rollers (**Fig. 3**) was judged and compared in terms of quantity of seed metered, volumetric cell fill percentage, seed germination, and seed damage as follows:

(a) Quantity of Seed Metered

The seed hopper was fitted with the roller to be tested and filled with the seed. The test was run for one-minute. The seed delivered by the roller was collected and weighed. Three replications were taken for each roller at each height, speed and seed variety. Similarly, the amount of seed delivered by the other three rollers were also collected and weighed.

(b) Volumetric Cell Fill Percentage

The number of seed collected/metered by the cell of the metering roller was measured in terms of volumetric cell fill percentage, expressed as under:

$$Vcf = [W/ (r \times n \times N \times V)] \times 100$$

Where,

Vcf: Volumetric cell fill, percentage

W: Weight of seed collected in one-minute (g)

r: Bulk density of metered seed, (g/cm^3)

n: Number of cells

N: Number of revolutions per minute

V: Volumetric capacity of each cell, (cm^3)

For selection of the optimum roller, the volumetric cell fill percent-

Particulars	Variety	
	MYCO-8 hybrid	HS-1 composite
Seed dimensions (mm)		
Length	11.23	12.1
Breadth	6.14	6.79
Thickness	3.63	4.52
Bulk density (g/cm^3)	0.424	0.408
Moisture content (%)	16.20	14.71

Table 2 Seed dimensions, bulk density and moisture content of MYCO-8 hybrid variety and HS-1 composite variety

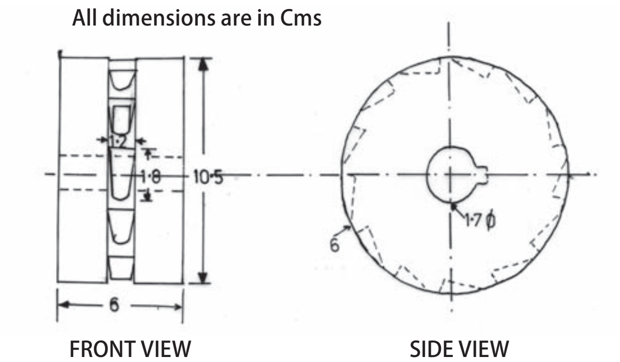

Fig. 2(1) Seed metering roller (R_1)

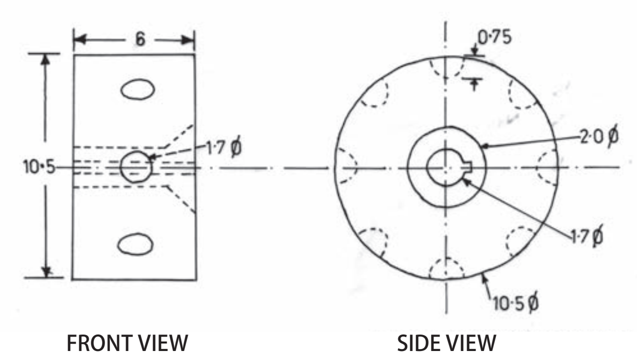

Fig. 2(2) Seed metering roller (R_2)

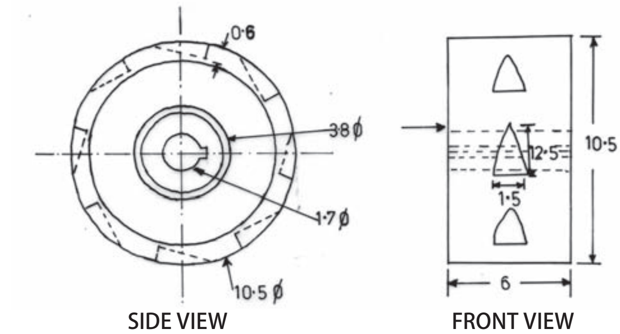

Fig. 2(3) Seed metering roller (R_3)

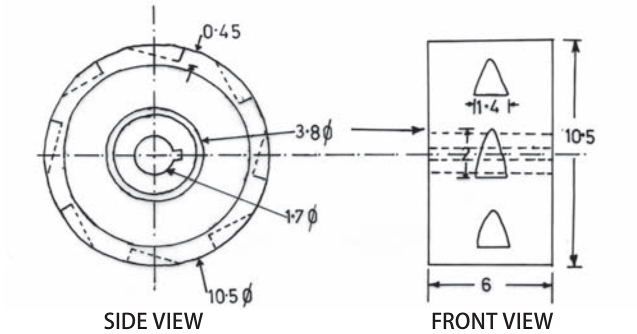

Fig. 2(4) Seed metering roller (R_4)

age of each roller was calculated and compared for both varieties.

(c) Seed Germination

The seed germination of both fresh and metered seed of all the samples under laboratory conditions were measured by sowing a counted number of seeds (30 seed sample) in G.I. sheet trays. The germination was counted ten days after sowing.

(d) Seed Damage

The extent of seed damage due to mechanical metering by rollers was calculated on the basis of laboratory germination test on metered and un-metered in all seed samples which was calculated as shown below:

Seed damage (%) = Germination of un-metered seed (%) - Germination of seed metered by the roller (%)

Results and Discussion

Evaluation of Crop Variables

Table 2 shows the seed dimensions, bulk density and moisture content of both varieties of sunflower. The dimensions of the MYCO-8 hybrid variety were smaller as compared to the HS-1 composite variety. The average bulk density was 0.424 and 0.4081 g/cm^3 for MYCO-8 hybrid variety and HS-1 composite variety, respectively. While moisture content was observed as 16.2 and 14.17 % for the MYCO-8 and HS-1 variety, respectively. The bulk density of seeds increased with increase in moisture content.

Evaluation of Machine Variables

(i) Quantity of Seed Metered

Table 3 indicates that with roller, R_3, the highest quantities of seed were metered in all the seed depths and speeds of operation and were highly significant as compared to R_1, R_2 and R_4. With roller, R_4, though the quantity of seed metered was lower than R_1, R_2 and R_3 for all speeds, it was capable of metering 2 to 3 seeds/cell which was a desirable feature for a planter. There was almost a linear relationship between quantity of seed metered and speed of operation with all the rollers except R_2, where an increase in quantity of seed metered was less as speed of operation increased from 33 rpm. This was because of the circular cell shape which may

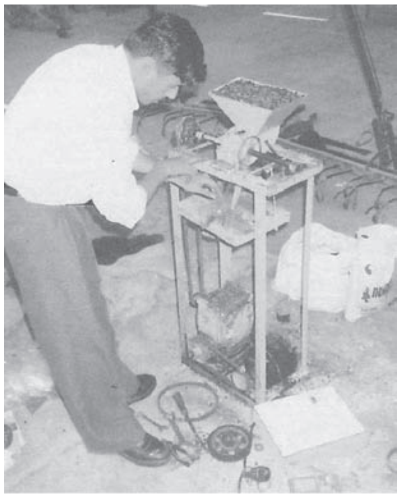

Fig. 3 Performance evaluation of seed metering rollers

Roller x height	MYCO-8, Hybrid					HS-1, Composite				
	V_1	V_2	V_3	V_4	Row mean	V_1	V_2	V_3	V_4	Row mean
R_1 x h_1	4.93	9.27	10.92	15.38	10.12	4.83	8.04	10.72	14.44	9.50
R_1 x h_2	5.41	9.33	11.43	15.85	10.50	5.09	8.21	11.15	14.83	9.82
R_1 x h_3	5.60	9.52	11.97	16.09	10.79	5.29	8.47	11.51	15.19	10.11
Mean	**5.31**	**9.37**	**11.44**	**15.77**	**10.47**	**5.07**	**8.24**	**11.12**	**14.82**	**9.81**
R_2 x h_1	11.04	18.33	10.82	28.20	19.59	10.96	16.30	19.20	27.30	18.44
R_2 x h_2	11.227	18.48	21.94	28.51	20.05	11.14	16.80	20.05	27.70	18.92
R_2 x h_3	11.58	20.66	22.72	28.73	20.92	11.31	19.73	21.52	28.10	20.16
Mean	**11.29**	**19.15**	**21.82**	**28.48**	**20.18**	**11.13**	**17.61**	**20.25**	**27.70**	**19.17**
R_3 x h_1	11.72	20.88	25.99	34.66	23.13	10.44	18.55	24.30	33.05	21.58
R_3 x h_2	12.02	21.25	27.01	35.22	23.87	11.68	19.58	25.17	33.65	22.52
R_3 x h_3	12.52	21.45	27.52	35.99	24.37	12.03	19.88	26.21	34.28	23.10
Mean	**12.08**	**21.19**	**26.60**	**35.29**	**23.79**	**11.38**	**19.33**	**25.22**	**33.66**	**22.40**
R_4 x h_1	5.04	7.56	9.68	13.12	8.85	4.20	7.18	9.49	12.05	8.23
R_4 x h_2	5.40	7.88	9.99	13.25	9.13	4.69	7.32	9.69	12.16	8.46
R_4 x h_3	5.69	8.15	10.28	13.79	9.47	4.83	8.02	10.17	12.45	8.86
Mean	**5.37**	**7.86**	**9.98**	**13.38**	**9.15**	**4.57**	**7.50**	**9.78**	**12.22**	**8.51**

Factor combination	**CD (5%)**	**CD (5%)**
Roller	0.0363	0.0392
Height (cm)	0.0315	0.0339
Speed (m/min)	0.0363	0.0392
Roller x height	0.0629	0.0678
Roller x speed	0.0727	0.0738
Speed x height	0.0629	0.0678
Roller x height x speed	0.1258	0.1357

Table 3 Quantity of seed metered by different rollers (g/min)

not fill properly at higher speeds. In other rollers, because of the uniform shape of cells, entry of seed, even at higher speed, was better. The quantity of seed metered by the rollers at 15 cm height in the hopper was maximum with R_3 (35.99 g/min), followed by R_2 (28.73 g/min), R_1 (16.09 g/min), and R_4 (13.79 g/min). This was because of better entry of seeds in the cells due to additional weight of seeds above the roller cells.

Table 3 also indicates that the roller R_3 metered the highest and R_4 metered the least quantity of seed with the HS-1 variety. The slightly reduced quantitiy of seed metered by all rollers with this variety was due to the varietal characters of shape, size of seed, and lower bulk density. Srivastava et al. (1988) reported that shape and size of the cells of seed metering rollers significantly affect the quantity of seed metered and seed occupancy of the cell. Ritu (1995) supported these results on mechanical metering of pre-germinated rice seeds.

(ii) Volumetric Cell Fill Percentage

Table 4 shows that the highest volumetric cell fill percentage was with roller, R_3 (20.45 %), at 15 cm seed-column height followed by R_4 (16.65 %), R_1 (14.55 %), and R_2 (13.45 %) all at 17 rpm roller speed with MYCO-8 hybrid variety. Though volumetric capacity of roller, R_4, was only 0.593 cm^3, because of the uniform triangular shape of cell, the seed entry was better as compared to rollers, R_1 and R_2. There was a highly significant decrease in the seed occupancy as the speed of the roller increased from 17 rpm to 70 rpm.

In HS-1 composite variety, roller, R_3 also gave highest average volumetric cell fill percentage (20.41 %) followed by R_4, R_1, and R_2, respectively, at 15 cm seed height in the box at 17 rpm roller speed. Due to difference in seed dimensions and other physical characteristics, slightly higher average values of cell fill percentage were obtained with MYCO-8 hybrid variety as compared to HS-1 composite variety.

(iii) Seed Germination

Table 5 shows that seed germination was highest with roller, R_4, (85.13 %) followed by R_1, R_2, and R_3, respectively, in MYCO-8 hybrid variety. Higher germination was recorded at 10 cm depth of seed in the box for all the rollers at all speeds. The seed germination was adversely affected by depth of seed column height in the hopper. This was because of seed damage by the roller at the cut-off device as more seeds entered the cells. As the roller speed was increased from 17 rpm to 70 rpm there was a reduction in seed germination for all rollers at all seed column heights in MYCO-8. However, on an average, lower seed germination was recorded for all rollers with the HS-1 composite variety. This could be due to varietal character and quality of seed. **Table**

Roller x height	MYCO-8, Hybrid					HS-1, Composite				
	V_1	V_2	V_3	V_4	Row mean	V_1	V_2	V_3	V_4	Row mean
R_1 x h_1	12.79	12.40	10.47	9.69	11.33	13.00	11.16	10.68	9.45	11.07
R_1 x h_2	14.05	12.47	10.96	9.98	11.86	13.73	11.39	11.11	9.71	11.48
R_1 x h_3	14.55	12.72	11.48	10.14	12.22	14.27	11.76	11.47	9.94	11.86
Mean	**13.80**	**12.53**	**10.97**	**9.93**	**11.80**	**13.66**	**11.43**	**11.08**	**9.70**	**11.47**
R_2 x h_1	12.84	10.99	8.95	7.96	10.18	13.25	10.15	8.57	8.01	9.99
R_2 x h_2	13.12	11.07	9.43	8.05	10.41	13.47	10.46	8.96	8.13	10.25
R_2 x h_3	13.45	12.39	9.76	8.11	10.92	13.68	12.28	9.61	8.24	10.95
Mean	**13.13**	**11.48**	**9.38**	**8.04**	**10.50**	**13.46**	**10.96**	**9.04**	**8.12**	**10.39**
R_3 x h_1	19.14	17.57	15.26	13.74	16.42	17.71	16.22	15.24	13.62	15.69
R_3 x h_2	19.63	17.87	16.30	13.96	16.94	19.82	17.11	15.78	13.86	16.64
R_3 x h_3	20.45	18.05	16.61	14.27	17.34	20.41	17.38	16.44	14.12	17.08
Mean	**19.74**	**17.83**	**16.05**	**13.99**	**16.90**	**19.31**	**16.90**	**15.82**	**13.86**	**16.47**
R_4 x h_1	14.73	11.39	10.45	9.32	11.47	12.78	11.23	10.65	8.89	10.88
R_4 x h_2	15.80	11.87	10.79	9.40	11.96	14.26	11.45	10.88	8.97	11.39
R_4 x h_3	16.65	12.27	11.11	9.78	12.45	14.67	12.55	11.42	9.18	11.95
Mean	**15.73**	**11.84**	**10.78**	**9.50**	**11.96**	**13.90**	**11.74**	**10.98**	**9.01**	**11.40**

Factor combination	**CD (5%)**	**CD (5%)**
Roller	0.0237	0.0282
Height (cm)	0.0205	0.0245
Speed (m/min)	0.0237	0.0282
Roller x height	0.0411	0.0489
Roller x speed	0.0474	0.0565
Speed x height	0.0411	0.0489
Roller x height x speed	0.0822	0.0978

Table 4 Effect of roller type, seed-column height in hopper and seed of operation on volumetric cell fill (percentage)

Roller x height	MYCO-8, Hybrid					HS-1, Composite				
	V_1	V_2	V_3	V_4	Row mean	V_1	V_2	V_3	V_4	Row mean
R_1 x h_1	85.44	84.43	82.18	80.07	83.03	80.07	79.47	75.08	74.22	77.21
R_1 x h_2	85.62	85.22	82.32	81.40	83.64	81.18	79.25	75.99	73.48	77.47
R_1 x h_3	85.99	85.59	82.40	80.29	83.56	80.99	79.39	75.10	74.26	77.43
Mean	**85.68**	**85.08**	**82.30**	**80.60**	**83.41**	**80.74**	**79.37**	**75.39**	**73.98**	**77.37**
R_2 x h_1	86.36	85.03	80.33	80.66	83.09	78.44	78.40	75.40	73.10	76.33
R_2 x h_2	86.06	84.81	80.26	78.95	82.52	80.55	78.58	74.10	72.48	76.42
R_2 x h_3	85.88	82.05	82.29	78.22	82.28	80.48	77.70	73.77	72.44	73.09
Mean	**86.10**	**83.96**	**80.96**	**79.30**	**82.63**	**79.82**	**78.22**	**74.42**	**72.67**	**72.28**
R_3 x h_1	86.66	85.25	78.26	77.67	81.96	80.88	77.40	73.14	72.40	75.95
R_3 x h_2	85.55	84.40	80.48	78.55	82.24	80.36	79.17	73.62	74.33	76.87
R_3 x h_3	86.36	85.22	81.43	77.58	82.64	79.90	77.70	76.07	74.44	77.02
Mean	**86.19**	**84.95**	**80.05**	**77.93**	**82.28**	**80.38**	**78.09**	**74.27**	**73.72**	**76.61**
R_4 x h_1	88.07	86.29	84.11	82.25	85.18	82.03	80.66	77.26	76.29	79.06
R_4 x h_2	87.29	87.03	83.36	82.36	85.01	82.18	81.29	77.40	75.41	79.07
R_4 x h_3	88.15	87.13	84.26	81.33	85.21	81.88	80.33	76.77	75.96	78.73
Mean	**87.84**	**86.81**	**83.99**	**81.98**	**85.13**	**82.03**	**80.76**	**77.14**	**75.88**	**78.95**
Factor combination			**CD (5%)**					**CD (5%)**		
Roller			0.1729					0.2339		
Height (cm)			0.1505					0.2026		
Speed (m/min)			0.1738					0.2329		
Roller x height			0.3010					0.4052		
Roller x speed			0.3457					0.4678		
Speed x height			0.3010					0.4052		
Roller x height x speed			0.6019					0.8103		

Table 5 Effect of roller type, speed of operation and seed-column height in hopper on seed germination

Roller x height	MYCO-8, Hybrid					HS-1, Composite				
	V_1	V_2	V_3	V_4	Row mean	V_1	V_2	V_3	V_4	Row mean
R_1 x h_1	4.55	5.56	7.48	9.92	6.87	4.92	5.52	9.91	10.78	7.78
R_1 x h_2	85.62	85.22	82.32	81.40	83.64	81.18	5.74	9.00	11.51	7.51
R_1 x h_3	85.99	85.59	82.40	80.29	83.56	80.99	5.60	9.89	10.74	7.55
Mean	**85.68**	**85.08**	**82.30**	**80.60**	**83.41**	**80.74**	**5.62**	**9.60**	**11.01**	**7.61**
R_2 x h_1	86.36	85.03	80.33	80.66	83.09	78.44	6.60	9.59	11.89	8.66
R_2 x h_2	86.06	84.81	80.26	78.95	82.52	80.55	6.41	10.89	12.52	8.56
R_2 x h_3	85.88	82.05	82.29	78.22	82.28	80.48	7.29	11.22	12.56	8.89
Mean	**86.10**	**83.96**	**80.96**	**79.30**	**82.63**	**79.82**	**6.76**	**10.56**	**12.32**	**8.70**
R_3 x h_1	86.66	85.25	78.26	77.67	81.96	80.88	7.59	11.85	12.59	9.03
R_3 x h_2	85.55	84.40	80.48	78.55	82.24	80.36	5.83	11.37	10.67	8.12
R_3 x h_3	86.36	85.22	81.43	77.58	82.64	79.90	6.14	8.93	10.55	7.68
Mean	**86.19**	**84.95**	**80.05**	**77.93**	**82.28**	**80.38**	**6.52**	**10.71**	**11.27**	**8.27**
R_4 x h_1	88.07	86.29	84.11	82.25	85.18	82.03	4.33	7.74	8.71	5.93
R_4 x h_2	87.29	87.03	83.36	82.36	85.01	82.18	3.71	7.59	9.59	5.92
R_4 x h_3	88.15	87.13	84.26	81.33	85.21	81.88	4.67	8.22	9.04	6.26
Mean	**87.84**	**86.81**	**83.99**	**81.98**	**85.13**	**82.03**	**4.23**	**7.85**	**9.11**	**6.03**
Factor combination			**CD (5%)**					**CD (5%)**		
Roller			0.1729					0.2339		
Height (cm)			0.1505					0.2026		
Speed (m/min)			0.1738					0.2329		
Roller x height			0.3010					0.4052		
Roller x speed			0.3457					0.4678		
Speed x height			0.3010					0.4052		
Roller x height x speed			0.6019					0.8103		

Table 6 Effect of roller type, speed of operation and seed-column height in hopper on seed damage

5 clearly shows that roller, R_4, having uniformly shaped small cells which can accommodate 2 to 3 seeds/cell at speeds of 33 to 40 rpm, is considered optimum for maximum seed germination in both the varieties.

(iv) Seed Damage

The damage to the seed varied from 1 to 13 % in both the varieties. **Table 6** shows that the least damage was observed with roller, R_4, at 15 cm height at 4 m/min (17 rpm) speed and maximum seed damage (12.41 %) was observed with roller, R_3, at 70 rpm with 15 cm height of seed column in the hopper. The lower seed damage with roller, R_4, was due to proper geometry of seed cells which accommodated 2 to 3 seeds/hill. However, when the speed of roller, R_4, was increased from 15 rpm to 70 rpm, the damage increased from 1.85 % to 8.67 %.

Similarly, with the HS-1 variety, higher seed damage was recorded with R_2 at all speeds and seed heights. The minimum seed damage (2.81 %) was observed with R_4 for HS-1 at 17 rpm. It was optimum for use in the sunflower planter up to 33 rpm. Similarly, for MYCO-8 variety, roller, R_4, up to 40 rpm of operation was optimum.

Conclusions

The roller, R_4, having uniformly shaped cell type (triangular small cell) with aluminum casting and 8 cells on its periphery, gave optimum seed quantity and cell fill percentage, maximum seed germination, and minimum seed damage. Thus, R_4 with speeds between 17 and 40 rpm, along with 15 cm height of seed in the box are optimum for use in development of a sunflower planter.

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Design Development and Performance Evaluation of a Saw Cylinder Cleaner for Mechanically Picked Cotton

by

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Abstract

A saw-cylinder cleaner was designed, developed and its performance evaluated. The major components of the machine were hopper, feeder, kicker cylinder, saw cylinders, doffing brush cylinders, loading brushes, grid bars and deflectors. The feeder received seed cotton from the hopper and delivered it to the kicker cylinder. The kicker cylinder loosened the seed cotton and kicked it to the first stage of the machine. Then, the seed cotton was reclaimed and further cleaned in the second and third stages of the machine, respectively. Trash removed in each stage and cleaned seed cotton were routed directly out of the machine. The capacity of the developed saw cylinder was found to be 800 kg seed cotton/hr. The stick removal efficiency and fine trash content removal percentage were found to be 87.0 % and 49.6 %, respectively. There was no measurable fibre damage observed during trash removal in all trials of cleaning operations whereas slight improvement in uniformity ratio was observed in all trials of cleaning operations.

Introduction

India ranks first in the world in area under cotton cultivation with 8.6 million ha during 2001-02 and the third largest producer of cotton fibre in the world after China and USA. The average productivity of cotton in the country is about 310 kg lint/ha as compared to a world average of 650 kg lint/ha. Nearly 60 % of cotton cultivation is grown under rain fed conditions and the remaining 40 % is irrigated (Narayanan and Sundaram, 1999). Indian cotton is the most contaminated cotton in the world and the main contaminants are plastic, plastic film, jute/hessian, leaves, feathers, paper, leather, sand, dust, rust, metal, wire, sticks and stems. (Santhanam and Sundaram, 1999).

Presently, in India, cotton, whether irrigated or rain fed, is entirely hand picked (Sandhar, 1999). One adult person can pick 20 to 70 kg of cotton per day as compared to 870 to 2180 kg per day by a single row spindle type cotton picker (Prasad and Majumdar, 1999). Hand picking is not only tedious, hard work but also ten times more costly than irrigation and about twice the cost of weeding. In recent years, it has been observed that there are labour shortages during peak periods of cotton harvesting. In order to meet the scarcity of labour, efforts need to be concentrated on mechanization of cotton harvesting. The use of the mechanical picking machine will minimize the drudgery involved in hand picking as well as enhancing production of a cleaner grade of seed cotton. The mechanical cotton picking system will also be helpful in achieving timeliness of operation for next crop.

Two types of mechanical harvesting equipment are used to harvest cotton; namely, spindle pickers and strippers (McMillan and Harrington, 1991). The picker is a selective-type harvester that removes seed cotton only from well-opened bolls. Green, unopened bolls are left on the plant to mature for later picking. The stripper is a nonselective or once over machine that removes not only the well-opened bolls but also cracked and unopened bolls along with the burs and other foreign matter (Miller, 1960; McMillan and Harrington, 1991).

Foreign matter concentration in machine picked seed cotton normally ranges from 5 to 10 percent before gin processing (Anthony, 1990). Approximately 80 % of this trash is composed of burs and sticks, which are large plant components. If large plant components are not removed from cotton, these components interfere with the operation of gin stand and contribute to the fine trash and bark content of the ginned lint (Baker and Laird, 1982). Stick removal is particularly important because of the close relationship between sticks content of cotton before ginning and bark content of the ginned lint (Laird and Baker, 1975).

A two-stage saw cylinder cleaner was designed, developed, and evaluated for its performance in an attempt to remove the large vegetative trash components present in mechanically harvested cotton. This machine used sling off action of high speed rotating saw cylinders by utilizing centrifugal force and the stripping action of round grids positioned about the circumference of each cylinder to extract burs and sticks from the cotton.

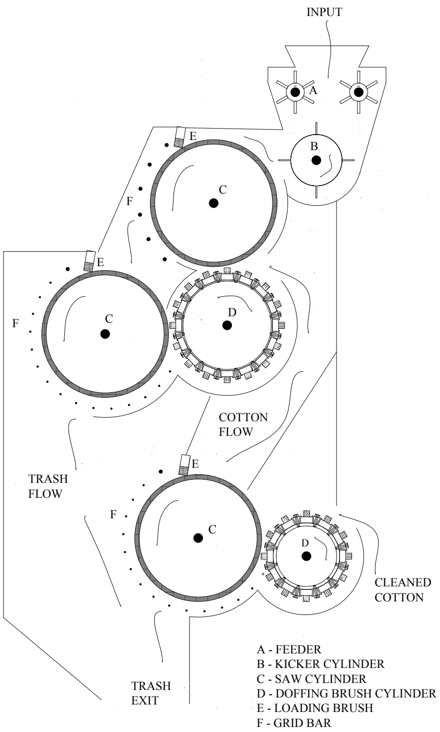

Fig. 1 Diagram of saw cylinder cleaner

Materials and Methods

The saw cylinder cleaner consisted of three saw cylinders, two doffing-brush cylinders, three loading brushes and three grid bars arranged in a special configuration which is illustrated schematically in **Fig. 1**. A side view of the developed saw cylinder cleaner is shown in **Fig. 2**. The height, width and length of the machine was 2100 mm, 240 mm, 1500mm, respectively. The first (top) saw cylinder served as the primary sling off cylinder for the first stage of extraction, and the second saw cylinder served as reclaimer for its seed cotton. The once-cleaned and reclaimed seed cotton was then redirected to the third saw cylinder for a second and final stage of cleaning. Trash removed was routed directly out of the machine. Doffing-brush cylinders were used to doff the cleaned seed cotton from each saw cylinder just after stripping action of round grids positioned about the circumference of each cylinder. The first doffing cylinder served for both first and second saw cylinders to reduce the height of the machine.

Fig. 2 Side view of saw cylinder cleaner

The function of each part and their brief description are as follows:

Hopper

A trapezium shaped hopper was placed at the top of the machine to feed the seed cotton. It has capacity to store 5-6 kg of seed cotton. There was an opening at the bottom of the hopper through which the seed cotton was fed to feeders.

Feeders

Directly below the hopper were the two feeder cylinders with a preset clearance between them to uniformly feed the seed cotton to a kicker cylinder. The required surface speed of the feeder cylinders for a uniform supply of cotton was obtained through reduction gears.

Kicker Cylinder

The kicker cylinder, as mentioned above, picks up cotton from the feeder cylinders. This cylinder had spikes all over its surface, which opened the wads and clods of seed cotton, and made the seed cotton suitable for saw cylinder cleaning. The kicker roller rotated at very high speed so that all the cotton adhering to it, along with the sticks and burrs, was loosened by centrifugal force and was kicked towards first saw cylinder.

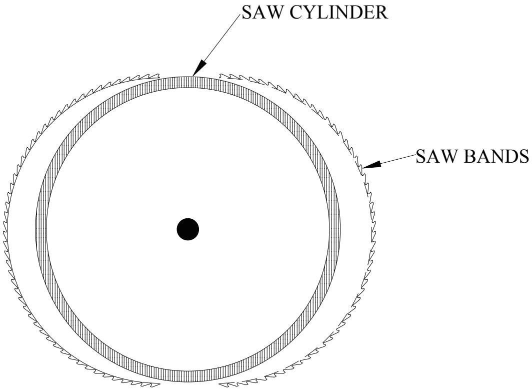

Fig. 3 Saw cylinder along with saw bands

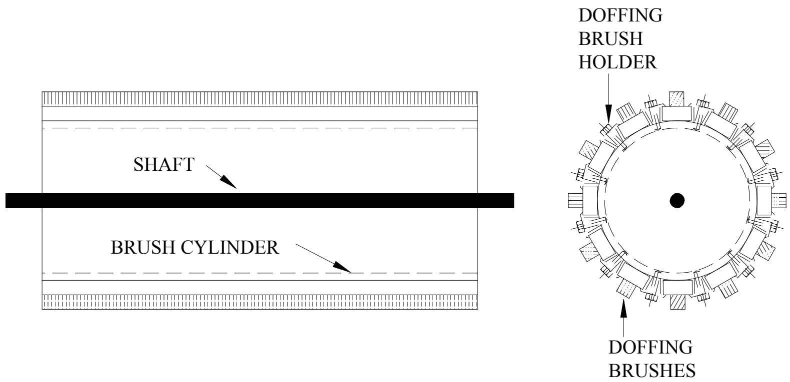

Fig. 4 Doffing brush cylinder

Saw Cylinders

The saw cylinders were used to remove the trash from the seed cotton. Specially designed saw bands, as shown in **Fig. 3**, were fitted over the periphery of saw cylinders. The saw bands are fabricated by cutting a typical profile on alloy steel sheets with the help of a punch and die. The saw bands were then bent in circular shapes and hardened to withstand the scrubbing force between saw teeth and the seed cotton. They were mounted over saw cylinders in such a way that the spacing between each saw band was equal to the width of an individual saw band. The surface speed of the saw cylinders was selected so that the centrifugal force was 20 to 30 times that of the force of gravity. This centrifugal force was quite sufficient to loosen the entangled sticks and burrs from the seed cotton.

Doffing Brush Cylinders

Doffing-brush cylinders were fabricated by mounting equally spaced nylon brushes over the periphery of steel cylinders as shown in **Fig. 4**. The bristle of brushes was securely fitted in wooden holders. In the present set up, the first doffing-brush cylinder was used for the first two saw cylinders to conserve space. The position of the axis of the cylinder with respect to the two axes of the saw cylinders was carefully adjusted for this purpose. There was also a provision to accurately adjust for the position of the axis in case of wear and tear of the bristles of the brushes.

Loading Brushes

A loading brush was placed on the top of each saw cylinder such that the cotton on the saw cylinders forced its way through the bristles before being scrubbed between the surface of the saw cylinder and a grid bar system. The loading brush further loosend the entangled sticks and burrs from the seed cotton. Thus, the heavier matter, such as burrs and sticks, were freed from the grip of saw teeth and resulted in their separation from the seed cotton.

Grid Bars

The grid bar system that enveloped (flanked) the saw cylinder on one side was made of two types of bars, as shown in **Fig. 5**. The first type of grid bar consisted of 11.6 mm diameter rods spaced at 200. The second type consisted of one rod of 11.6 mm diameter with the other rods having a 5.4 mm diameter. The angle between the first and second rods was 160 and the angle between the other rods was 13.80. The bars were attached near their ends to two arc-shaped rectangular plates such that the system of bars and plates assumed the shape of a bent ladder. The rungs of the ladder were equally spaced except for the two top rungs where the spacing was somewhat larger than the other pairs. This arrangement allowed for speedy removal of heavy trash through the top two rungs of the grid. The cotton was then scrubbed between the remainder of the grid bars and any loose, lighter trash was hurled through the grid bars towards a trash, screw conveyor.

Deflectors

Right below each saw cylinder was a thin plate a small distance from the tip of saw teeth. The seed cotton, after leaving the grid bars, was carried forward through the narrow passage between this plate and

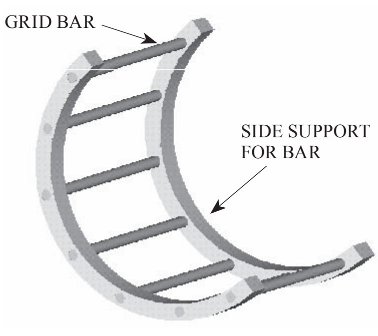

Fig. 5 Grid bar assembly

the saw cylinder towards a doffing-brush cylinder. The gap was narrow so that only cotton was allowed towards the doffing brushes. The sticks and burrs, if any, were blocked and fell on a second saw cylinder for further cleaning. The loading brush, grid bars, blocking plate and doffing-brush cylinder stages were provided for the saw cylinder. Additional design details for this machine are given in **Table 1**.

Performance Evaluation

Five sets of trials were conducted to assess the performance of the developed saw-cylinder cleaner. For these trials, this machine was installed in our laboratory. Five hundred kg of seed cotton was used in each trial from a single lot. The cotton was fed manually and uniformly to the machine in each trial. Since machine-picked cotton was not available in India, 400 cotton plant sticks were added and thoroughly mixed in the seed cotton prior to cleaning in each trial. The stick sizes were selected in such a way that it would simulate machine-picked cotton. The total number of sticks removed in each trial was counted to assess the stick removal performance of the machine. The cleaned seed cotton obtained from each trial and the control seed cotton were ginned on double roller (DR) gins. The lint samples obtained after ginning were analysed on MAG-SITRA trash separator for fine trash content and on High Volume Instrument (HVI) for its fibre properties which were 2.5% span length, uniformity ratio, fineness and strength.

Results and Discussion

The fibre properties, trash content and time required to clean the seed cotton are shown in **Table 2**. The output capacity of this machine, percentage of sticks removed and percentage of fine trash content removed are shown in **Table 3**.

The capacity of the developed saw cylinder was found to be 800 kg seed cotton/h. The stick removal efficiency of the machine ranged from 84.5 % to 90.0 % for the five trials conducted with average of 87.0 %. Percentage of fine trash content removal was found to be in the range of 43.8 % to 58.3 % for the five trials conducted with average of 49.6 %. Fine trash content removal percentage was lower as the machine was designed for removing large plant components (sticks and burrs). The 2.5 % span length of lint fibres varies from 21.9 to 22.2 mm for different trials as well as for control. It is evident that no fibre damage occurred while in the developed saw cylinder cleaner. However, slight improvement in uniformity ratio was observed in each trial due to separation of short fibres during cleaning operations.

Conclusions and Recommendations

• The overall performance of the developed machine was satisfactory

• The capacity of the developed

Items	Specifications	Items	Specifications
Saw Cylinder		**First Grid Bar**	
Diameter, mm	420	Diameter, mm	11.6
Saw band width, mm	16	No. of rods	7
Saw band spacing, mm	16	Angular spacing, deg	20
Operating speed, rpm	360	Clearance to saw, mm	12.5
First Doffing Brush Cylinder		**Second Grid Bars**	
Diameter, mm	398	Firsr rod	
No. of brushes	16	Diameter, mm	11.6
Operating speed, rpm	1,080	Angular spacing, deg	16
Second Doffing Brush Cylinder		Other rods	
Diameter, mm	314	Diameter, mm	5.4
No. of brushes	12	No. of rods	15
Operating speed, rpm	1,080	Angular spacing, deg	13.8
		Clearance to saw, mm	12.5

Table 1 Design characteristics of saw cylinder cleaner

Experiment	Time required to process (s)	No. of sticks removed	Fine trash content (%)	2.5 % Span length (mm)	Uniformity ratio (%)	Fineness (Micronaire)	Bundle strength (g/tex)
Control	-	-	4.8	25.6	45	4.1	22.2
Trial 1	2,325	360	2.4	25.3	46	4.0	21.9
Trial 2	2,212	352	2.1	25.4	47	4.1	22.0
Trial 3	2,362	340	2.8	25.4	46	4.1	21.8
Trial 4	2,295	350	2.4	25.5	48	4.0	22.1
Trial 5	2,235	338	2.2	25.3	46	4.1	21.9

Table 2 Fibre properties, trash content and time required to clean seed cotton

Experiment	Capacity (kg/h)	Sticks removed (%)	Fine trash content removed (%)
Trial 1	774.2	90.0	50.0
Trial 2	813.7	88.0	43.8
Trial 3	762.0	85.0	58.3
Trial 4	784.3	87.5	50.0
Trial 5	805.4	84.5	45.8
Average	≈ 800.0	87.0	49.6

Table 3 Output capacity, percentage of sticks removed and percentage of fine trash content removed

saw cylinder was found to be 800 kg seed cotton/h.

• The stick removal efficiency was found to be 87.0 percent.

• Percentage of fine trash content removal was found to be 49.6 percent.

• There was no measurable fibre damage observed during trash removal in all trials of cleaning operations.

• Slight improvement in uniformity ratio was observed in all trials of cleaning operations.

• More stages of cleaning saw cylinders may be incorporated to increase the efficiency of the machine.

• Grid bar spacing may be varied to increase the efficiency of the machine.

• The performance of the machine may be evaluated after varying the saw band spacing over the saw cylinders.

• The performance of the machine may be evaluated after changing the saw band tooth profile.

• For better performance of the machine, well opened seed cotton specially pre-cleaned in a cylinder cleaner should be used.

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Design Development and Performance Evaluation of Portable Cotton Ginning Machines

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Abstract

The cotton breeder must ascertain the fibre properties (span length, fibre fineness, maturity, strength) and ginning percentage (GP) for hundreds of new strains when selecting for further propagation. The fibre properties of cotton also determine the price and are invariably taken into consideration by traders while buying the cotton. Hence, to facilitate cotton breeders, traders and farmers, two portable type cotton ginning machines, a foot operated gin and the *Lilliput* gin, were designed at Ginning Training Centre of Central Institute for Research on Cotton Technology (CIRCOT), Nagpur (India). The foot operated gin and the *Lilliput* gin have a ginning output capacity of 311 g lint/h and 2111 g lint/h respectively. The 2.5 % span length and uniformity ratio remained practically same for hand ginning, foot operated gin and the *Lilliput* gin. The machine parameters have no damaging effect on fibre properties or seed quality. Both gins are well accepted in the commercial market and, at this time, 20 foot operated gins and 75 Lilliput gins are in use in agricultural universities, seed industries, ginneries and with the farmers. The foot operated gin is much more suitable for farmers because it is economical and auxiliary power is not required for its operation. The *Lilliput* gin is the most popular amongst the cotton breeders, traders and seed industries.

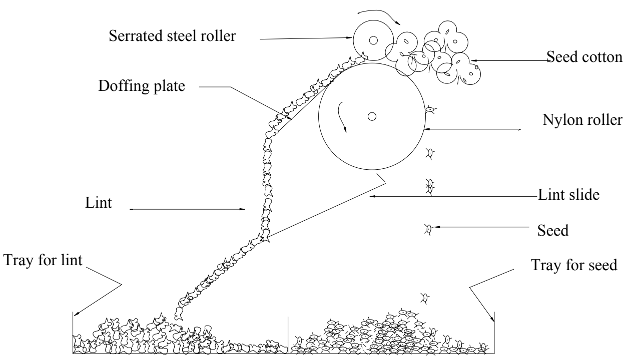

Fig. 1 Principal of operation of foot operated gin

Introduction

India has the most land in cotton production of any country in the world with about eight million hectare and is third in total cotton production with 2.5 million tonnes. India now produces all the different quality cottons for the domestic need and has some remaining for export.

The quality of cotton fibres, as they develop in the bolls on the plant, is mainly dependent on the pedigree of the plant and the conditions under which the plant is grown. This inherent quality can be improved upon only by cross breeding, selection and adoption of appropriate agronomic practices, but no improvement is possible after the cotton boll on the plant opens. The important criteria chosen by the cotton breeder while selecting a new strain for further propagation are 2.5 % span length, strength, micronaire, uniformity ratio (UR), maturity and ginning percentage (GP). The breeder must ascertain the above fibre properties for hundreds of strains with small samples of seed cotton every year as accurately as possible in a short time. The cotton grower must assess the monetary return from the crop by knowing fibre properties and GP since cotton with higher GP and better fibre properties will bring a better price. Further more, in cotton markets for seed cotton, the lint content of the seed cotton is estimated by the purchaser/broker by the usual hand-and-eye judgement, which is bound to involve large personal errors.

Most seed in the market contain mixtures of different varieties due to malpractices and mixing of different varieties in cotton markets and in ginneries. Hence farmers are not getting pure and quality seeds for planting. Further, seed available in the market are costly. In India, mostly roller and saw gins are used for commercial ginning. These machines are impracticable for breeders, traders, and farmers when ginning small samples to obtain ginning percentages. In addition, these machines are more costly and are not portable.

A portable ginning machine was needed to overcome the problems faced by the cotton breeder, trader, seed industries and farmers. Thus, a portable type foot operated gin and the *Lilliput* Gin were designed and fabricated at the Ginning Training Centre, Central Institute for Research on Cotton Technology (ICAR) Nagpur (India) -PIN-440 023.

Materials and Methods

The Foot Operated Gin and *Lilliput* Gin were designed based on the market needs. An extensive market survey was conducted with different user groups to determine their requirements in terms of utility, output capacity and cost. Two kinds of user groups were identified depending on the above factors. The foot operated gin was designed for an output of 1 kg seed cotton/h and the *Lilliput* gin was designed for an output of 6 kg seed cotton/h. These two machines were designed and developed and their performance evaluated and compared to that of the hand ginning method.

Foot Operated Gin

The principle of operation of the foot operated gin is shown in **Fig 1**. This is a pedal operated machine in which a pair of counter rotating rollers is employed to pinch and pull out fibres from the seeds. The seed cotton is fed by the operator between the rollers by hand and the lint caught between the roller is drawn out, pulled from the seed and carried forward by the nylon roller from which it is stripped by the lint doffer. The seeds are collected in a separate tray.

The design of the foot operated gin is very simple (**Fig. 2**). It consists of two cylindrical rollers 253 mm length. The upper roller (diameter 20 mm) is serrated and made of mild steel. The lower roller is made of Nylon-12 and its diameter is 53.5 mm. The peripheral speed of both the rollers is 0.36 m/s. The gap between two rollers varies from 0.10-0.13 mm. In addition to the ginning rollers, the machine consists of a lint doffer, a lint slide, a frame and operator's seat. A V-belt and pulley are provided to transmit the power from the bicycle pedals to the ginning roller. This machine does not require electric power and can be operated by one unskilled operator. The base of the machine is 570 x 565 mm and the height of the machine is 1150 mm. The weight of the machine is 45 kg. The foot operated gin with operator is shown in **Fig. 5**.

Power Transmission

Number of pedals per minute = 42 (1 pedal/1.4 s.)

RPM of nylon roller = 127

RPM of grooved roller = 341

Speed ratio: Nylon roller: Grooved roller =1:2.6

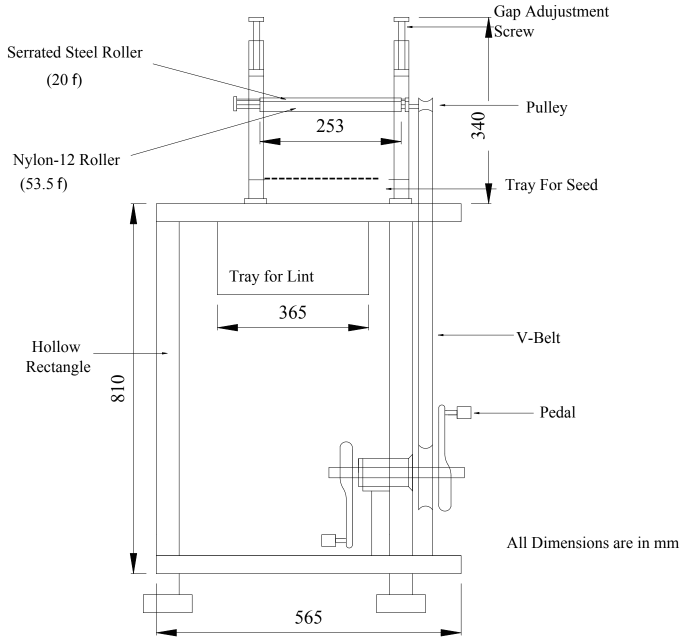

Fig. 2 Design details of foot operated gin

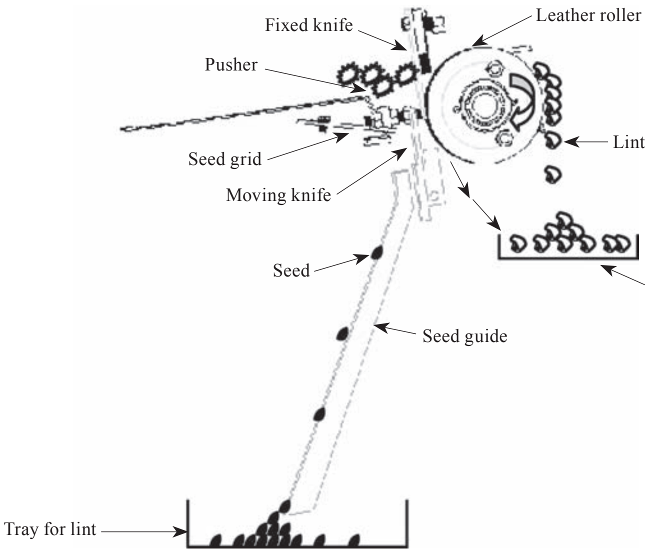

Fig. 3 Principal of operation of *Lilliput* gin

***Lilliput* Gin**

This power operated portable gin works on the principle of Macarthy's gin. A chrome leather roller, fixed knife and moving knife are the main components of the gin. A spirally grooved roller is pressed against a fixed knife and is made to rotate at a definite speed. A moving knife reciprocates by means of a crank or eccentric shaft near the leather roller. When seed cotton is fed into the operating machine the fibre adhere to the rough surface of the roller and are carried in between the fixed knife and the roller such that the fibres are partially gripped between them. The moving knife beats the seeds and separates the fibres, which are gripped from the seed end. This "push and pull" action separates the the fibres from the seed. The separated fibres are carried forward on the roller, pass upward and are dropped out of the machine. The ginned seeds drop down through the grid slots provided. The *Lilliput* gin is shown in **Fig. 3.**

The main frame of the machine is fabricated from cold rolled sheet metal. The moving knife and the fixed knife are made from EN-8 alloyed steel. The roller is made of chrome composite leather. The machine is powered by a single-phase, one-hp electric motor. The eccentric shaft is fixed between the two metal sheets and is driven by a belt and pulley mechanism from the motor. The power to drive the roller is supplied by a chain and sprocket mechanism driven by an eccentric shaft. The eccentric shaft drives and reciprocates the moving knife and the pusher, which helps feed the seed cotton at the ginning point. Two screws are provided to adjust the height of the fixed knife, which adjusts the overlap between the fixed knife and moving knife. Slots are provided on bearing housings of the roller to adjust the pressure between the fixed knife and roller. A suitable mechanism is provided to adjust the gap between the fixed and moving knife. The schematic diagram of the gin is shown in **Fig. 4**.

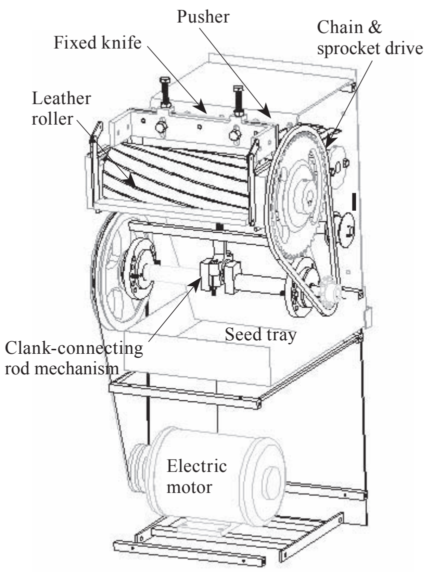

Fig. 4 Schematic view of *Lilliput* gin depicting internal mechanisms

The length and diameter of the roller is 254 mm and 100 mm respectively and rotates at 120 rpm. The moving knife reciprocates at 480 strokes per minute. Grooves on the surface of the roller are 25 mm apart and the width and depth are 2 mm. A wooden flat is placed on the front side of the roller to avoid backlash. The lint collection tray is just below the roller and the seed collection tray is beneath the seed grid. A small rectangular hopper is used to feed the cotton. The belt pulley and chain sprocket have safety guards and handles are provided on both the sides of the machine for ease in handling. The base of the machine is 400 mm x 340 mm, the height is 650 mm and the weight is 70 kg. A pictorial of the *Lilliput* gin is shown in **Fig. 6.**

Performance Tests

Both the developed gins were tested to evaluate the performance

Fig. 5 Foot operated gin in operation

in terms of ginning output, ginning percentage and fibre quality parameters which are 2.5% span length, fineness, uniformity ratio, strength and quality of seeds obtained. The varieties selected for testing the performance of the gins were: four *G. arboreum* (LD.327, K.10, AKH.4 & Y.1); six *G. hirsutum* (LRA.5166, H.777, Suman, G.Cot.10, Abadhita & Sharda); one *G. harbaceum* (G.Cot.11); and five Hybrids (DCH.32, NHH.44, H.4, H-6, Ankur.651). All the selected varieties were also hand ginned for comparison.

A 100 g seed cotton sample was ginned for each variety by the foot-operated gin, a 500 g seed cotton sample was ginned by the *Lilliput* gin and a 100 g sample was ginned by hand. Triplicate tests were made for each cotton and method of ginning. The lint out put per hour and ginning percentage (GP) were calculated for each variety. The lint samples obtained from machine ginning and hand ginning were tested for the fibre properties (2.5 % span length, fineness and strength) on the state of the art High Volume Instrument (HVI-900) manufactured by M/S. Zellweger Uster, (USA) approved by USDA.

Fig. 6 *Lilliput* gin in operation

Cotton variety	Hand ginning		Foot operated gin		Lilliput gin	
	Output (g/h)	GP (%)	Output (g/h)	GP (%)	Output (g/h)	GP (%)
G. arborium						
LD.327	16.0	41.53	250	42.2	1,962	41.6
K.10	14.1	34.73	355	36.3	2,330	35.0
AKH.4	15.8	34.13	375	36.9	2,156	35.4
Y.1	15.8	35.30	375	38.4	2,142	35.3
Mean	15.4	36.42	338.7	38.4	2,147.5	36.8
G. hirsutum						
LRA.5166	14.6	35.4	371	37.1	2,151	35.3
H.777	15.2	32.0	270	34.7	2,082	33.6
Suman	16.9	33.3	323	37.5	2,118	35.3
G.cot.10	15.3	36.9	234	36.7	2,089	36.2
Abadhita CPD 8-1	14.7	35.9	226	36.4	1,930	36.1
Sharda	14.2	39.6	229	38.2	1,963	37.6
Mean	15.1	35.5	275.5	36.7	2,055.5	35.6
G. harbeceum						
G.cot.11 Hybrid	14.2	36.0	317	35.0	2,141	35.8
DCH.32	13.2	31.6	347	32.1	2,154	31.7
NHH.44	13.7	35.2	323	35.0	2,005	35.3
H.4	14.2	34.1	295	34.0	2,137	34.3
H.6	14.3	35.0	300	34.2	2,083	34.7
Ankur.651	14.0	34.5	301	34.3	2,111	33.9
Mean	13.8	34.1	313	33.9	2,098	33.9
Grand Mean	14.6	35.5	311	36.0	2,111	35.5

Table 1 Ginning output and ginning percentage of lint by hand ginning, foot operated gin and *Lilliput* gin

The ginning percentage (GP) of a given sample was calculated by using the following formula

Ginning Percentage (%) = (Weight of lint/ Weight of seed cotton) x 100

Results and Discussion

The output of lint per hour and GP of 16 cotton varieties, when ginned by all the three methods (hand ginning, foot operated gin, and the *Lilliput* gin) are given in **Table 1**. Overall lint output of the foot operated gin and *Lilliput* gin was about 311 g/h (i.e. about 1 kg seed cotton/h) and 2111 g/h (i.e. about 6 kg seed cotton/h) respectively. The GP of the seed cotton for the foot operated and the *Lilliput* gin was 36 % and 35.5 % respectively. The ginning output and GP by hand ginning was 14.6 g/h (i.e. about 50 g seed cotton/h) and 35.5 % respectively. The GP values of *arboreum* cottons were higher compared to those of *hirsutum, herbaceum* and hybrid cottons. The statistical analysis shows that variance in GP is due to varieties.

Table 2 presents fibre properties (2.5 % span length, uniformity ratio, strength and fineness (micronaire)) of lint obtained from the three methods. These fibre properties remained practically the same whether the cotton was ginned by hand or in the foot operated gin or the *Lilliput* gin. The statistical analysis showed that the variance due to gin treatment was not significant. Thus, both the machines could be used for all scientific work and also in trade.

The cost of the foot operated gin is about US $ 200 and that of the *Lilliput* gin is about US $ 600. The foot operated gin and the *Lilliput* gin are well accepted in the commercial market and so far 20 foot operated gins and 75 *Lilliput* gins are in use in various cotton research institutes, agricultural universities, cotton markets, ginneries, seed industries and with the farmers. The foot operated gin is found to be much suitable for farmers because it is economical and electrical power is not required for its operation but the *Lilliput* gin is the most popular amongst the cotton breeders, traders, ginneries and seed industries.

Conclusions

• The foot operated gin and the *Lilliput* gin were designed and developed to give an output of 1 kg seed cotton/h and 6 kg seed cotton/h respectively.

• Both the machines are simple and robust in construction. The overall performance of the gins was satisfactory and found technically and economically viable.

• No damage to the lint and seed was observed.

• Both the gins are commercialized and are popular amongst the cotton research institutes, agricultural universities, cotton breeders, ginneries, seed industries and farmers for ginning small samples for quality evaluation, for identifying ginning percentage and for seed production for planting.

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Cotton variety	Hand ginning				Foot operated gin				Lilliput gin			
	SL (mm)	Str (g/t)	Mic	UR (%)	SL (mm)	Str (g/t)	Mic	UR (%)	SL (mm)	Str (g/t)	Mic	UR (%)
G. arborium												
LD.327	20.13	16.9	7.1	48.3	20.43	16.7	6.7	47.9	20.26	16.5	6.9	48.1
K.10	28.1	24.9	4.4	48.0	29.23	24.6	4.2	47.5	28.33	24.3	4.3	48.3
AKH.4	27.93	22.6	4.5	50.3	27.76	22.2	4.4	49.3	27.36	22.3	4.5	49.6
Y.1	22.46	24.7	4.7	48.7	22.56	24.3	4.5	49.1	22.66	24.2	4.5	48.5
Mean	24.66	22.3	5.2	48.8	24.9	22.0	5.0	48.45	24.65	21.8	5.0	48.6
G. hirsutum												
LRA.5166	29.1	25.2	3.8	45.3	29.06	25.4	3.6	45.5	29.0	25.6	3.7	47.0
H.777	25.46	22.5	4.3	48.3	25.86	22.3	4.4	48.5	25.2	22.5	4.3	48.2
Suman	25.1	23.6	4.0	47.0	25.56	24.5	4.2	48.1	25.4	21.6	4.1	46.4
G.cot.10	25.1	22.6	4.2	51.3	24.7	22.7	4.5	50.1	24.7	22.3	4.3	49.2
Abadhita CPD 8-1	24.2	22.4	3.5	49.0	24.9	22.7	3.5	48.0	24.7	22.6	3.4	49.3
Sharda	23.80	22.3	4.2	50.3	23.93	22.5	4.2	50.1	23.7	22.4	4.2	50.4
Mean	25.46	23.1	4.0	48.5	25.66	23.3	4.0	48.3	24.11	22.8	4.0	48.4
G. harbeceum												
G.cot.11 Hybrid	25.13	22.8	4.2	49.7	24.9	22.6	4.3	48.8	24.7	22.3	4.1	49.3
DCH.32	33.7	30.1	3.1	44.7	32.23	30.0	3.4	44.8	32.9	29.4	3.0	44.8
NHH.44	25.53	24.1	3.8	47.0	25.66	24.0	3.8	47.0	25.4	24.1	3.8	47.9
H.4	27.9	24.5	4.2	50.3	28.03	24.3	4.3	50.1	27.53	24.1	4.1	50.0
H.6	28.8	25.3	3.8	47.3	28.6	25.1	3.7	48.1	28.4	25.3	3.9	47.3
Ankur.651	28.2	22.3	3.5	45.0	28.3	22.3	3.4	45.1	28.2	22.8	3.5	46.6
Mean	28.82	25.2	3.6	48.8	28.5	25.1	3.7	47.0	28.4	25.1	3.7	47.3
Grand Mean	26.02	23.3	4.2	48.9	25.9	23.2	4.2	48.1	25.4	23.0	4.2	48.4

Table 2 2.5 % span length (SL), strength (Str), fineness (Mic) and uniformity ratio (UR) of lint of different varieties by hand ginning, foot operated gin and *Lilliput* gin

Design and Development of Power Operated Roller Type Lac Scraper

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Abstract

Lac is the hardened resin secreted by the tiny lac insect. Lac insects thrive only on certain trees called lac hosts. Butea monosperma (*Palas*), Zizyphus mauritiana (*Ber*) and Schleichera oleosa (*Kusum*) are the major lac hosts used in India. Lac cultivation involves five major operations which are pruning, inoculation, used up broodlac (*phunki*) removal, harvesting and lac scraping. Mostly, lac cultivation operations are carried out manually with the aid of locally manufactured traditional tools. Manual lac scraping is a very slow and tedious process. In one method, farmers sit on the ground in a group and scrape lac with the traditional tools like a small scraping knife (*dauli*) and sickle. In another method, farmers remove lac encrustation by beating lac sticks with bamboo stick. One person scrapes 5-10 kg of lac in a day. As scraping is done on the ground, unwanted foreign materials like sand, soil, and wooden twigs find their way into scraped lac, reducing the price to farmers and creating problems during lac processing in industries. In order to increase the output and reduce the drudgery of lac production, a simple power operated roller type lac scraper was designed and developed. The machine consists of a scraper, separation screen, feed hopper, drive mechanism and machine frame. The machine scrapes lac under the action of shear and compressive forces. One person operates the machine and scraps about 13.5 kg lac stick in an hour with scraping efficiency of 95 percent.

Introduction

Lac scraping involves removal of lac encrustation from lac sticks. Traditionally lac encrustation is removed either by scraping with the help of tools such as a scraping knife and sickle.or by beating lac sticks with a bamboo stick. About 95 % of farmers use a scraping knife. (Prasad, 1999). The process is very tedious and slow. Since the scraping is carried out on the ground, many unwanted foreign materials such as soil, sand, and stick pieces find their way into the scraped lac, reducing return to farmers and creating problems during lac processing in industries. A manual lac scraper was developed at the Agricultural Engineering Department, Birsa Agricultural University, Ranchi, India (Pandey and Majumdar, 1997). However its popularity was reduced due to its limited capacity and functional limitations. An electrically operated lac scraper - cum - grader was developed at CIPHET, Ludhiana, India (Anon., 1998). Prasad et al. (2000) and Prasad et al. (2001) reported that the high cost reduced its popularity among lac growing farmers. In this study a low cost Power Operated Roller Type Lac Scraper was designed and developed.

Materials and Methods

The power operated roller type lac scraper is shown in **Fig. 1**, **2**, **3** and

4. The machine scrapes lac under action of shear and compressive forces. The construction details and testing are discussed below.

Scraping Rollers

Scraping rollers were the main components of the machine and were comprised of two corrugated mild steel rollers 125 mm diameter and 200 mm long. One of the rollers was fixed and other was spring loaded (spring constant of 24.5 kg/cm), and thus adjustable. They rotated in opposite directions at a speed differential of 1:1.6. In idle condition, the gap between the fixed and the adjustable rollers was 2 mm. As the stick moved between the rollers, the spring loaded roller caused compression against the stick. Lac removal resulted from the compression of the spring and the scraping action (shear force) resulting from the differential speed of the rollers.

Separating Screen

A 10-mesh sieve was fitted at an inclination of 450 from horizontal under the two scraping rollers to receive the scraped lac and stick. Most of the lac encrustation of less than 10 mesh size passed through the sieve and fell on the inclined pan, which guided the material toward the outlet of the machine. The scraped lac encrustation that did not pass through the sieve along with the sticks, slid down the sieve and came out of the machine.

Feed Hopper

The feed hopper was situated at the upper portion of the machine and was used to feed and guide the lac sticks between scraping rollers safely.

Drive Mechanism

The machine was powered by a 0.25 hp, single-phase, 1450 rpm motor. V-belts transmitted power to the rollers with a pulley reduction ratio that drove the rollers at 25 and 40 rpm, respectively, for the fixed and adjustable scraping rollers.

Machine Frame

The basic structure of the machine frame on which the various components were fixed, was made from mild steel angle iron (35 x 35 x 5 mm). The feed hopper frame was made of mild flat steel (25 x 5 mm).

Testing

The machine was tested using kusmi lac stick (used up broodlac or phunki). An operator fed lac stick into the machine by hand. A basket filled with lac stick was kept on a platform raised to the level of the feeding hopper for the convenience of the operator.

The following performance parameters of the Power Operated Roller Type Lac Scraper were determined.

Capacity: The capacity was measured by calculating the weight of the scraped lac stick per unit time (kg/h).

Scraping Loss: The scraping loss was measured in terms of percentage of lac encrustation that remained unscraped and carried along with the lac stick.

Results and Discussions

The capacity of the machine was found to be 13.5 kg/hr. Thus, the capacity for an 8 hour day was 108 kg lac stick as compared to 10-15 kg for one person with traditional tools like the scraping knife. The machine increased the output about seven times as compared to manual scraping and two times as compared to scraping with a pedal operated lac scraper (Prasad et al., 2002). The

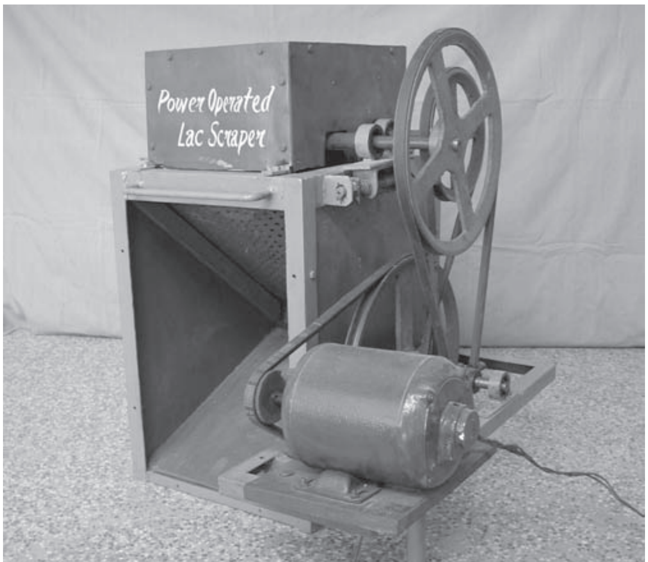
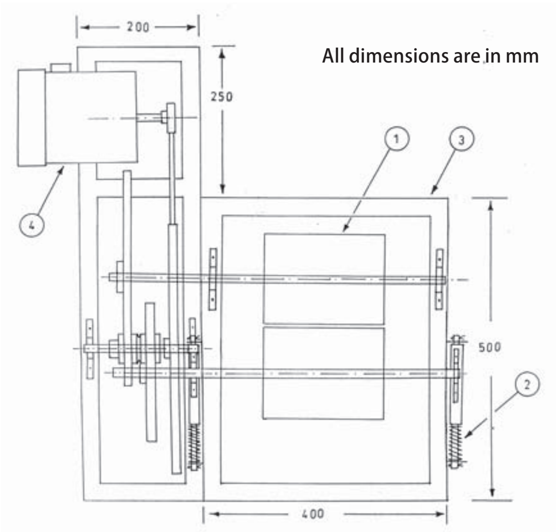


Fig. 1 Power operated roller type lac scraper



1. Scraping roller
2. Scraping roller gap adjustment mechanism
3. Machine frame 4. Motor

Fig. 2 Top view of power operated roller type lac scraper scraping efficiency was 95 % after passing lac sticks twice through the machine. Thus, 5 % lac encrustation remained on the lac stick even after the lac sticks were passed twice through the machine. If remaining lac encrustation was not manually scraped it was lost. Only one person was required to operate the machine. The machine was less expensive and simpler in comparison with the lac-scraping-cum-grading machine (Anon., 1998), and is in an affordable range for lac growing farmers. Further, skilled labour was not needed for operation and it required less maintenance.

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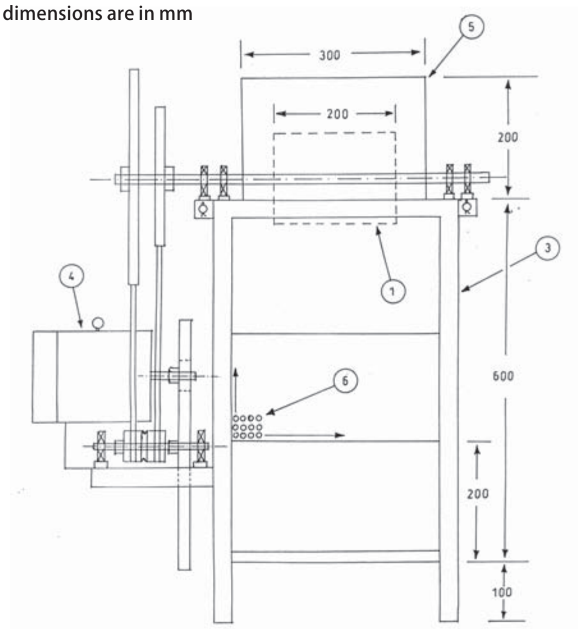
■■

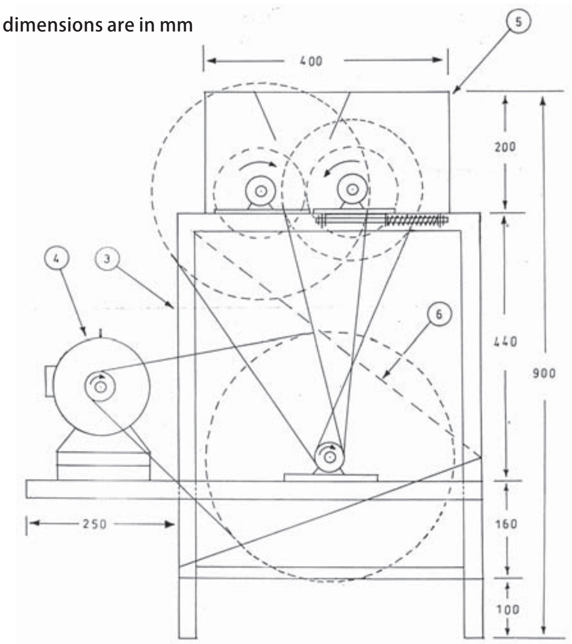
All dimensions are in mm



1. Scraping roller 3. Machine frame
4. Motor 5. Feed hopper
6. Sieve

Fig. 3 Front view of power operated roller type lac scraper

All dimensions are in mm



3. Machine frame4. Motor
5. Feed hopper 6. Sieve

Fig. 4 Side view of power operated roller type lac scraper

The Impact of Power Tillers on Small Farm Productivity and Employment in Bangladesh

by

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Abstract

Bangladesh agriculture is currently experiencing rapid growth in the adoption of power tillers (PTs) for land preparation. Earlier research (Gill, 1984) suggested that mechanisation was adopted by larger farmers and had a negative impact on employment opportunities for landless labourers, the availability of land for tenants (sharecroppers) and had little impact on productivity (yields). This study concluded that the adoption of PTs for land preparation is an efficient strategy for the management of labour and farm power as their use is associated with:

• A reduction in the costs of production for all sizes of farm

• Higher gross margins for all sizes of farm

• Greater labour productivity for all sizes of farm

• Increased demand for hired labour

• Small but measurable increases in opportunities for sharecropping

The overall impact of the use of PTs has been positive both in terms of economic value and social effects. Therefore, planners and policy makers should not be seriously concerned about the impact of PT mechanisation on the poor because:

• All farmers and labourers can benefit from mechanisation.

• Farm incomes improve

• Mechanisation of other tasks such as transplanting and harvesting are much more likely to have negative social effects, given that these are the most labour demanding tasks.

• Landless labourers benefit from improved employment opportunities

The present trend towards mechanisation of cultivation operations does not generally disadvantage the rural poor; however, there is some displacement of permanent farm labour. This displaced labour is presently finding alternative occupations in the expanding wider economy of the country. As long as this trend continues, PT adoption may be regarded as having neutral or positive effects on the livelihoods of the poor. However, changes in price structures for inputs and outputs may have a wider effect and these should be monitored and analysed.

Introduction

Bangladesh is predominantly an agricultural country with a total land area of about 14.4 million ha of which around 90 % is under cultivation. Most of this area is relatively flat and lies in the deltaic plains of the Padma, Jamuna, Brahmaputra and Meghna river systems. The principal crops grown in Bangladesh are rice, wheat, jute, pulses, oilseeds, potato, sugarcane, tea, tobacco and spices.

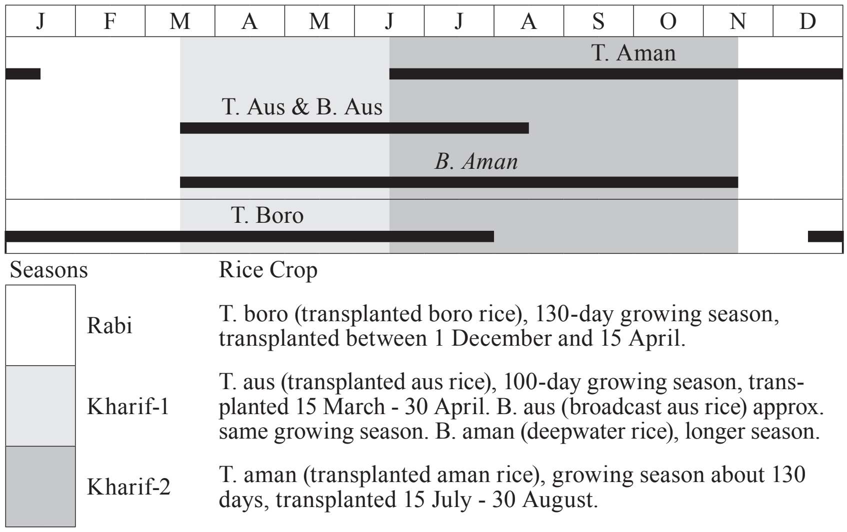
Farm power plays a crucial role in crop production in Bangladesh. Access to labour and farm power - human, animal and mechanical - determines the scale of farming operations. Power for lifting water for irrigation is closely associated with increases in land productivity, which are crucial to the intensification of agriculture; however, increases in the area irrigated can in turn lead to increased demands for power and labour.

With almost the entire possible arable area of Bangladesh under cultivation, it is apparent that increased production must be achieved through greater cropping intensity (more than one crop per year) or through increased yields per unit area. A constraint to achieving this has been identified as shortage of draught power, formerly provided mostly by cattle (Mettrick and James, 1981; Hermans, 1984; ULG, 1986; Daniels, 1987). This is the result of reduced land and feed resources and increased demand for draught power at peak periods. One solution has been to increase the use of cows for draught (Matthewman, 1987; Matthewman and Foulds, 1988).

A further solution, and one which has become widespread in recent years has been to mechanise cultivation using power tillers (PTs), since these can cultivate more quickly than draught animals (Pallis et al, 1983; Bunyavejchewin et al, 1993). Between 1980 and 1987, under a bilateral agreement between Bangladesh and Japan, Kubota and Yamaha brands of PTs were imported into Bangladesh. Chinese models, mainly Dong Feng and Saifeng were also imported at this time and were considerably cheaper than the Japanese models, despite the high levels of import duty levied. Following the severe floods of 1988, the Bangladesh Government withdrew tariffs and taxes on imported PTs and a large number of PTs entered the market from the People's Republic of China (PRC) and Korea. Prices of PTs fell dramatically and the numbers imported increased. Tariffs have not been re-imposed and retail prices of the Chinese PTs are still low today at approximately US$ 1200 for a 7 kW machine. It is argued (Planning Commission 1997, Miah, 2000) that agricultural mechanization can help in improving productivity, reducing costs of production, and increasing input use and efficiency as well as achieving timeliness of crop production.

A number of potential problems may arise from this policy. Draught animals have traditionally provided family security, manure and income from calves or rental and have been used for threshing and out of season uses such as transport, as well as cultivation. The adoption of power

Fig. 1 Generalised cropping calender for principal rice-based farming systems in Bangladesh



Souce: Modified from Sims (1994)

tillers may thus disturb the existing asset bases of farmers and also have direct effects on production through changes in the maintenance of soil fertility. The available literature indicated there had been little investigation of the impact of the use of mechanical sources of power for small farming in Bangladesh since Gill's major study in the early 1980's (Gill, 1984) and that of Jabbar et al. (1983). These studies indicated that the use of PTs, while profitable for their owners, seriously affected the incomes of marginal farmers, sharecroppers and landless labourers while contributing little to the overall productivity of the farming system. The study reported here[1] aimed to address these issues which are of crucial importance in Bangladesh where poverty remains the single most important social and economic challenge facing the country.

Cropping Systems and Cropping Intensity

Great changes in the cropping systems of Bangladesh have taken place over the last 20-30 years with the widespread introduction of irrigation from both deep tubewells (DTWs) and shallow tubewells (STWs) for dry season (winter) irrigation of rice. As a result of this, the cropping intensities of nearly all parts of the country showed considerable increases over this period (**Table 1**).

Before irrigation became popular the principal cropping systems in most parts of the country were based on *Aus* rice (planted March-May in the early rains or *Kharif-1* season) and Aman rice (planted July-September in the mid-to late-rains or *Kharif-2* season). Since the advent of irrigation, the pattern has changed to *Aman - Boro*, the latter being the irrigated crop planted in December to April during the dry winter (*Rabi*) season (most of the

Table 1 Multiple cropping indices (cropping intensities) for Bangladesh

	1960	1980	1998-99	
	National	National	National	Project farmers
Small (0-1.01 ha)	167	181	n/a	167-207[1]
Medium (1.02-3.04 ha)	152	167	n/a	189-200[2]
Large (>3.04 ha)	135	152	n/a	190-200[3]
Average	n/a	165	176	195

Souce: Gill (1983), [1]This study "Landless, marginal & small" category (<1.01 ha); [2]This study "Medium" category (1.02-2.02 ha); [3]This study "Large" category (>2.02ha)

[1]Funds for this research were provided by the Natural Resources Systems Programme of the Department for International Development (DFID), UK. The authors also acknowledge the contributions of BAU scientists and farmers of Mymensingh and Tangail Districts

rice crops are transplanted and prefixed "*T*", although some are broadcast, prefixed "*B*"). The cropping calendars for rice, that is *Aus*, *Aman*, *Boro* and the usually geographically separate system of deep water rice - carried out on the coastal and permanent water body margins of the country - are complex and largely determine the demand for draught power (Richards, 1979). Peak demand coincides with the turnaround time between crops. Timeliness in cultivation at these times is critical (Orr et al, 1986), placing a heavy demand on power resources. But the changed cropping pattern cited above has implications for the timing and pressure on cultivation power sources. Cropping patterns are shown in the **Fig. 1**.

The implications and opportunities (including the effect on crop yields) that arise from an increased use of power tillers was investigated at the farm level to examine their impact on power availability, yields, capital inputs, labour use, livestock production, landless labour and sharecropping. The results will help in the planning of improved extension inputs and support for power tiller and draught animal use and development.

Study Location

Figures on PT use obtained from the Department of Agricultural Extension indicated that the districts where the sample villages are situated, Tangail and Mymensingh, rank 8th and 10th, respectively, out of the 64 districts of Bangladesh in terms of numbers of PTs. Therefore the study area offered a picture of an advanced state of PT adoption compared to the national situation. The location of the study area and the sampled villages is shown in **Fig. 2**.

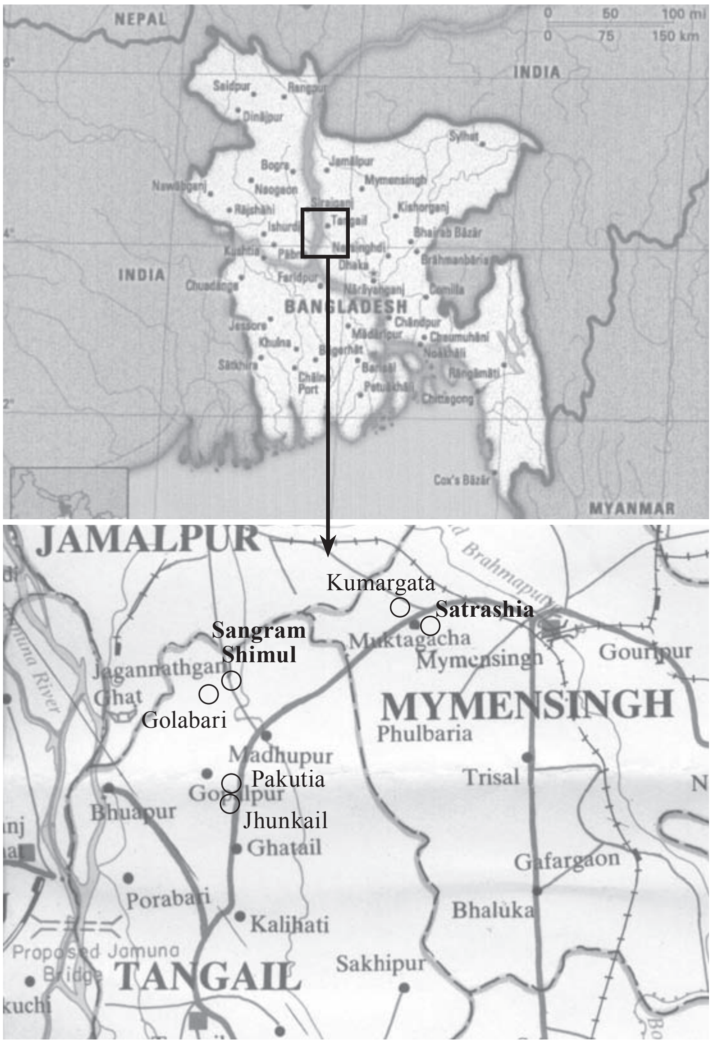


Fig. 2 Location of study areas

The agro-ecological zone (AEZ), the Old Brahmaputra Floodplain, AEZ 9, in which the villages are located, occupies some 5 % of the country's land area and is ranked as the 8th largest AEZ in the country. It resembles, in terms of land type (elevation and soils), other AEZ's in the Ganges[2] and Karatoya - Bangali flood plains, which, together with the Old Brahmaputra Floodplain, occupy some 21 % of the country's land area. There is very little deep-water rice on the single annual crop system in the area. This practice is common in the coastal areas and the lowest lying areas of the country.

The most common cropping patterns in the study area were "Fallow - Boro[3] - T. Aman[4] " and "Mustard - Boro - T. Aman". The sampled farms have a higher level of cropping intensity (multiple cropping index) - 195 % - than the national average of 176 %.

Availability and Distribution of Farm Power

A baseline survey of 198 households was undertaken to establish the extent of PT use in study villages as well as land ownership patterns, tenure and access to land of the different categories of farmers. Landless, marginal, small, medium and large farmers had average holdings of cultivable land of 0.2, 0.41 and 0.78, 0.96 and 1.80 hectares respectively.

[2]The Ganges flood plain soils are, however, more alkaline

[3]Boro: the winter (dry season) irrigated rice crop

[4]T. Aman: the rainy season transplanted rice crop

Sample farmers owned a total of 17 PTs and 145 draught animals (DA). They had a total of 422 permanent male workers at their disposal (including family labour) (**Table 2**).

The estimated power available to sample farmers in the six villages is shown in **Table 3**, excluding casual or migrant labour.

The total power available per hectare on sample farms was higher than the national average (0.39 kW/ha, Sarker, 1997) as a result of a high concentration of PTs in the study area. **Table 4** demonstrates that the majority of farmers - 177 (89 %) use PTs for land preparation. The growth in the use of PTs for land preparation was confirmed during a participatory exercise undertaken in 1999. The six villages collaborating with the study reported that the total number of PTs had increased from 13 in 1995 to 36 in 1999.

The introduction of PTs has had a significant impact on the numbers of cattle kept by farmers. The baseline survey indicated a steady decline as farmers withdrew draught animals from their farms (**Table 5**).

Power Sources and Other Inputs Used by Farmers

A weekly survey was designed to collect information from 482 pre-selected plots belonging to sample farmers, a visit was made each week for a period of 14 months to record all farm activities on these plots (January 1999 to March 2000). The main objectives of this survey were to quantify the impact of PTs on land and labour productivity, labour use, yields and margins.

A two way (village and farm category) stratified sampling technique was followed. The sample sizes for different strata (a combination of a village and a farm category) were not proportional to the corresponding population sizes but were determined by subjective allocation (considering size, heterogeneity and availability of project resources). More than 100 separate pieces of data (variables) were collected for each plot, including:

- Area, soil-type, topography and ownership of the plot, variety
- Human labour used (in hrs) by its source (e.g. family, hired, male, female, casual, permanent) for the following operations: cleaning, ploughing, laddering, seedling transfer, sowing, transplanting, irrigation, application of fertiliser, pesticides and herbicides, harvesting, transport and threshing.
- Animal labour used (in hrs) for ploughing, laddering, transport, threshing etc. Types of animal used (a pair of cows, bulls, or mixed)
- PT hours used for ploughing, laddering, transport, threshing
- Material inputs (quantity and cost): Seed, Manure, Urea, TSP, SSP, MP, Zinc, Gypsum, Pesticides, herbicides, fuel, electricity etc.
- Outputs: grain and straw

Figure 3, **4** and **Table 6** demonstrate that the majority of farmers use PTs for land preparation. Only

Table 2 Distribution of PT, DA and human labour (sample farmers)

Name of village	No. of working person (male)	Permanent employed labour (male)	No. draught animals	No. of PTs
Pakutia	86	-	19	4
Jhunkail	93	6	55	6
Sangram Shimul	38	5	11	2
Golabari	57	4	33	1
Satrashia	62	8	6	2
Kumargata	58	5	21	2
Total	394	28	145	17

Souce: Baseline survey date, 1999

Table 3 Distribution of power available in the study area (sample farmer)

Name of village	Total cultivable land area (ha)	Power from working person (kw)	Power from draught animal (kw)	Power from power tiller (kw)	Power available/ha (kw/ha)
Pakutia	67.64	5.16	3.14	28	0.53
Jhunkail	64.47	5.94	9.08	42	0.88
Sangram Shimul	35.22	2.58	1.82	14	0.52
Golabari	47.67	3.66	5.45	7	0.34
Satrashia	52.55	4.20	0.99	14	0.37
Kumargata	74.11	3.78	3.47	14	0.29
Total	34.66	25.32	23.95	119	0.49
Cotribution for land preparation (%)		15	14	71	

Calculations in Table 3 are based on the following standard units: PT = 7 kw, Male DA = 0.18 kw, Female DA = 0.15 kw, Male human = 0.06kw, Cropping intensity is 215 %.
Souce: Baseline survey date, 1999

Table 4 Use of PTs and DAs by sample farmers (no. of farmers using each source of power)

	Landless	Marginal	Small	Medium	Large	Total
Own oxen	5	6	6	10	6	33
Own cows	9	9	12	9	5	44
Rented oxen	2	2	3	2	1	10
Rented cows	1	0	0	0	0	1
Own PT	4	6	0	4	5	19
Rented PT	41	37	32	31	17	158

Souce: Baseline survey date, 1999

27 farmers used DAP excusively although many used a combination of PTs and DAs.

The study established that the adoption of PTs is widespread (in the study area) and the machines are used by all sizes of farms. PTs are not only used by the larger farmers that were formerly the case (Gill, 1984). PT cultivation is perceived to be faster than DAP and given that installed capacity is increasing, queuing for contract services (as reported by Gill, 1984) may be a thing of the past.

Yields and Returns

PTs have little impact on rice yields (**Table 7**). Although PT users have statistically significant higher yields than DAP users for Boro rice (R^2 = 0.29), the increase is small. Significant differences in yields were found between varieties and the use of family labour had a significant and positive impact on yields (i.e. farms that used more family labour had higher yields). The use of urea and ash were also important factors for higher yields.

Yields of Aman rice were similar for both power sources and differences were not significant (R^2 = 0.54). Yield differences between villages were significant, Pakutia having the highest yields and Kumargata the lowest. There were no differences between the other villages. Choice of variety and urea use had a significant and positive impact on yield.

PTs improve farmers' gross margins as production costs decrease (**Table 7**) (mechanical cultivation uses less human labour than DAP cultivation) and benefit: cost ratios (BCR) are therefore higher. PT users are likely to have higher incomes than DAP users (per unit of production). PTs also have the effect of reducing the management required for production (supervision costs are reduced) and also probably reduce the labour and management required to maintain draught animals. These savings are of greater importance to larger farmers. The major benefits accruing to smaller enterprises are reduced production costs but hiring PTs also reduces the need for smaller farmers to maintain draught animals.

Fig. 3 Distribution of power options on Boro plots

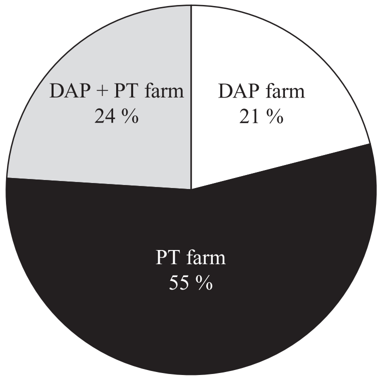


Fig. 4 Distribution of power options on Aman plots

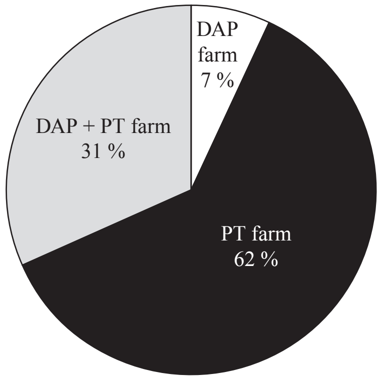


Table 5 Time series date on cattle ownership 1994-98 (n=198)

Year	1994	1995	1996	1997	1998
Draught oxen	160	155	116	87	68
Draught cows	142	136	114	93	87
Milk cows	99	115	100	99	94
Calves	77	79	72	91	-
Buffaloes	4	2	2	0	0

Souce: Baseline survey date, 1999

Table 6 Types of power used on plots surveyed during the weekly survey

	DA	Both	PT	All
Village:				
Pakutia	8	57	33	98
Jhunkail	8	73	17	98
Sangram Shimul	-	14	50	64
Golabari	9	49	16	74
Satrashia	-	6	68	74
Kumargata	2	23	49	74
Farm category:				
Landless	3	15	34	52
Marginal	12	34	58	104
Small	6	72	42	120
Medium	6	51	39	96
Large	-	50	60	110
All	27	222	233	482

Labour Productivity and Use

The use of PTs for rice production improves labour productivity (the yield or quantity of grain produced by each unit of labour) (**Table 8**). The increase in the productivity of labour with the adoption of PTs is 20 % for Boro (significant $p<0.01$) and 18 % for Aman (not significant).

Family Labour

The use of PTs for land preparation is associated with increases in the demand for hired labour and reductions in the use of family labour. It is not clear whether family labour is redeployed elsewhere or benefits from increased leisure time. Despite being a labour saving technology - it reduces the human labour required for land preparation - the introduction of PTs has probably provided employment opportunities for labourers. Farms using DAP for land preparation use equal amounts of family and hired labour whereas PT farms use twice as much hired labour as family labour.

Landless Labour

Participatory exercises with landless labourers confirmed that PTs reduce daily wage labour employment opportunities for land preparation (ploughing with DAs). Larger farmers also reduce the number of permanent labourers they employ (there is less need to maintain draught animals). However, the increase in the availability of irrigation water has altered cropping patterns and increased the demand for labour for transplanting and harvesting. Labourers also reported an increase in non-farm employment opportunities (where wages are higher) and an increase in the real value of wages over the past decade. On balance they felt their livelihoods had improved following the introduction of PTs, (although this was not a causal relationship).

Landlord / Tenant Relations

Earlier research in the field of agricultural mechanisation (PTs) in Bangladesh reported that the adoption of PTs reduced opportunities for sharecropping as landlords 'took in hand' land that was formerly let to tenants or sharecroppers (Gill, 1984). Participatory research undertaken by this project indicates that this is no longer the case.

Table 9 shows the changes in size of holding of sharecroppers in each village after the introduction of PTs. With the exception of Sangram Shimul, total cultivable land of sharecroppers has increased following mechanisation (most of the farmers in Sangram Shimul are resource poor farmers with little land available to let). Land available to sharecroppers has increased for the following reasons:

• Cost of production increases has discouraged landlords from cultivating their own land or to acquire more land to sharecrop with others.

• The supply of available labour is often insufficient and labour wages therefore increase, consequently, larger farmers prefer to rent out land to sharecroppers.

• The number of absentee landlords may have increased (migration), thus improving the opportunities for sharecropping.

However, it is DAP owners rather than PT owners or users who have been offered more land for sharecropping. Landlords appreciate the benefits of organic material (manure) and anticipate higher yields from the use of DAP. Ownership or access to DAP (and manure) may be a precondition for access to rented land (sharecropping).

Conclusions

PTs have the following impact on most farming systems of Bangladesh:

• Little or no impact on yields

• A reduction in the costs of production for all sizes of farm

• Higher gross margins for all sizes of farm

• Greater labour productivity for all sizes of farm

• Increased demand for hired labour

• Small but measurable increases in opportunities for sharecropping

On balance, the overall impact of the use of power tillers has been

Table 7 Impact on yields and returns

Power source	DAP	PT	Both
Boro Rice			
Yield (kg/ha)	5,307	5,385	5,483
Gross return (Tk/ha)	38,635	39,202	39,916
Net return (Tk/ha)	8,774	12,785	12,641
BCR (undiscounted)	1.29	1.48	1.46
Aman Rice			
Yield (kg/ha)	3,540	3,580	3,530
Gross return (Tk/ha)	26,373	26,671	26,298
Net return (Tk/ha)	12,373	13,746	13,388
BCR (undiscounted)	1.88	2.06	2.04

Souce: Weekly survey date, 1999-2000

Table 8 Labour productivity

Power source	Human labour (hrs/ha)	Yield (kg/ha)	Yield per unit of human labour (kg/hr)
Boro Rice			
DAP	1,431	5,307	3.70
PT	1,212	5,385	4.44
Difference PT - DAP	-219	+78	+0.74
Aman Rice			
DAP	1,184	3,540	2.99
PT	1,015	3,580	3.53
Difference PT - DAP	-169	+40	+0.54

Souce: Weekly survey date, 1999-2000

positive both in terms of economic value and social effects. Therefore planners and policy makers should not be seriously concerned about the impact of PT mechanisation on the poor because:

• All farmers and labourers can benefit from mechanisation.

• Farm incomes improve

• Mechanisation of other tasks such as transplanting and harvesting are much more likely to have negative social effects, given that these are the most labour demanding tasks.

• Landless labourers benefit from improved employment opportunities

The present trend towards mechanisation of cultivation operations does not generally disadvantage the rural poor. This study has demonstrated that farms using DAP for land preparation use equal amounts of family and hired labour whereas PT farms use twice as much hired labour as family labour. It is not clear whether this family labour, including women and children, is redeployed elsewhere or benefits from increased leisure time. It is possible that the decline in cattle numbers, by reducing the tasks of animal husbandry, has benefited women and children who previously bore this responsibility to a large extent. The main responsibility of women is post-harvest operations (threshing/winnowing) and PTs have made little impact on the labour demands for these tasks. The study therefore found no evidence of important effects of the adoption of PTs on women and children

However, there is some displacement of permanent farm labour. This displaced labour is presently finding alternative occupations in the generally expanding wider economy of the country. As long as this trend continues, PT adoption may be regarded as having neutral or positive effects on the livelihoods of the poor. However, changes in price structures for inputs and outputs may have a wider effect and these should be monitored and analysed.

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Table 9 Changes in size of land holding of sharecroppers after introduction of power tillers (ha)

Village	Before introducing PT, 1988			After introducing PT, 1999			Difference in size of holding (±)
	Land rented in	Land owned	Total	Land rented in	Land owned	Total	
Pakutia, n=10	2.570	0.425	2.996	3.198	0.425	3.623	0.627
Jhunkail, n=10	3.259	0.834	4.093	3.320	0.834	4.154	0.060
Sangram Shimul, n=5	1.880	0.182	2.064	1.032	0.170	1.202	-0.862
Golabari, n=6	0.770	1.032	1.801	1.214	0.607	1.821	0.020
Satrashia, n=6	2.093	1.391	3.484	2.222	1.645	3.868	0.385
Kumargata, n=6	0.878	1.615	2.494	1.599	0.901	2.500	0.006
Total of all locations, n=43	11.453	5.479	16.933	12.587	4.583	17.170	0.237
Average of all locations	1.908	0.913	2.822	2.097	0.764	2.862	0.040
Percentage of total in each year	67.64	32.36	-	73.31	26.69	-	-

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Field Performance Evaluation of Power Tiller Operated Air Assisted Spraying System

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Abstract

A power tiller operated sprayer was designed and developed considering spraying requirements of the mango tree and available power at the flywheel of a power tiller. Field evaluation of the sprayer was done for droplet distribution over the leaf area. Spraying was carried out at three blower speeds (2250, 2500 and 2800 rpm) and three different liquid discharge rates for each blower speed. Observations were taken at 12 locations in the canopy of the mango tree and two leaf surface areas (upper leaf and lower leaf) by glossy papers. All the samples were analyzed for droplet density and Volume Mean Diameter (VMD). The best results were obtained at 2250 rpm blower speed and 600 cc/min liquid discharge rate. At this treatment, the minimum value of droplet density was 06 droplets/sq cm and a VMD of 220 µm was observed at the inner side of the top tree canopy position with maximum respective values of 47 droplets/sq. cm and 450 µm at the bottom outer position of the tree canopy.

Introduction

India is the largest producer of mango in the world with an annual production of 9.5 million tones. However, many detrimental insects such as mango hopper, mealy bug, fruit fly, shoot borer, stem borer, mango scale insects and mango shoot gall maker cause damage to mango quality and quantity every year. Also, many diseases such as anthracnose, powdery mildew, brown rot, leaf blight and pink disease damage the mango tree.

Existing hydraulic sprayers have many limitations which include non-uniform spraying, particularly on the under leaf area and the top and inside portion of the mango tree canopy, and ineffective use of chemicals. An air carrier sprayer was designed and developed especially for the mango tree that would be powered by the fly wheel of a power tiller. The principle of operation of an air carrier sprayer with the mango tree is to replace all the existing air in the tree canopy with the spray-laden air that will deposit uniformly on every part of the canopy. Thus, if the sprayer is properly designed and operated, more uniform distribution might be obtained as compared to hydraulic sprayers.

Volume mean diameter (VMD) and droplet density are the two prime factors of droplet distribution pattern which determine effectiveness of pest control. Smith et al. (1975) recommended droplet size between 140 µm and 200 µm to be used for spraying most crops. They found that at 200 µm VMD, a droplet density of 20-25 droplets/sq cm was most effective for control of boll weevil on cotton. Anon. (1970) studied the adequacy of droplet density using ULV sprayer and recommended that an average of 15 to 20 droplets/sq cm was adequate for

Table 1 Average discharge rate at used at different speeds of blower

Blower speed (rpm)	Nozzle disc used	Discharge (cc/min)
2250 (S_1)	D_1	600
	D_2	700
	D_3	840
2500 (S_2)	D_1	750
	D_2	890
	D_3	1120
2800 (S_3)	D_1	930
	D_2	1000
	D_3	1380

Note: S = Speed of impeller, D = Liquid discharge, cc/min
S_1 = 2250 rpm: D_1 = 600 cc/min, D_2 = 700 cc/min, D_3 = 840 cc/min
S_2 = 2500 rpm: D_1 = 750 cc/min, D_2 = 890 cc/min, D_3 = 1120 cc/min
S_3 = 2800 rpm: D_1 = 930 cc/min, D_2 = 1000 cc/min, D_3 = 1380 cc/min

controlling most insects and pests. Alms et al. (1987) studied the effect of actual ingredient, droplet size and distribution on egg deposition and control of adult mites. They found that 41 droplets/sq cm at 120 µm VMD or 18 droplets/sq cm at 200 µm VMD eliminated 80 percent of egg deposition.

Material and Methods

A centrifugal type of air carrier sprayer was designed and developed to meet the requirements of the mango tree that could be driven by the fly wheel of power tiller. Field experiments were conducted in the mango garden of ASPEE Farm, Tansa (Dist. Thane, Maharashtra) to study the performance of the pesticide application system. The independent parameters were impeller speed, target location, liquid discharge rate, leaf surface, leaf traverse location and leaf transverse location. Plant to plant distance was 10 m. Crown diameter and heights ranged between 8 to 13 m and 7.5 to 12.5 m respectively. Randomized Block Design was used with a total of 27 selected plants. There were nine treatments with 3 impeller speeds and three discharge rates (**Table 1**). Each trial was replicated 3 times. Impeller speeds were selected considering a design speed of the blower as 2500 rpm. The blower speeds for the experiment were taken above and below the design speed (2250, 2500 and 2800 rpm). Liquid discharge rates were selected after calibration of three nozzle discs (D_1, D_2, and D_3). The discharge of each disc increased with blower speed as shown in **Table 1**. The crown of the trees under treatment was divided into three sections (top, middle and bottom) considering their individual heights. It was also divided into four sections vertically (top-inner and top-outer at each half section of tree). In this way 12 glossy papers of 4.5 cm x 6 cm size were fixed at the upper leaf surface and 12 at the lower leaf surface in each tree

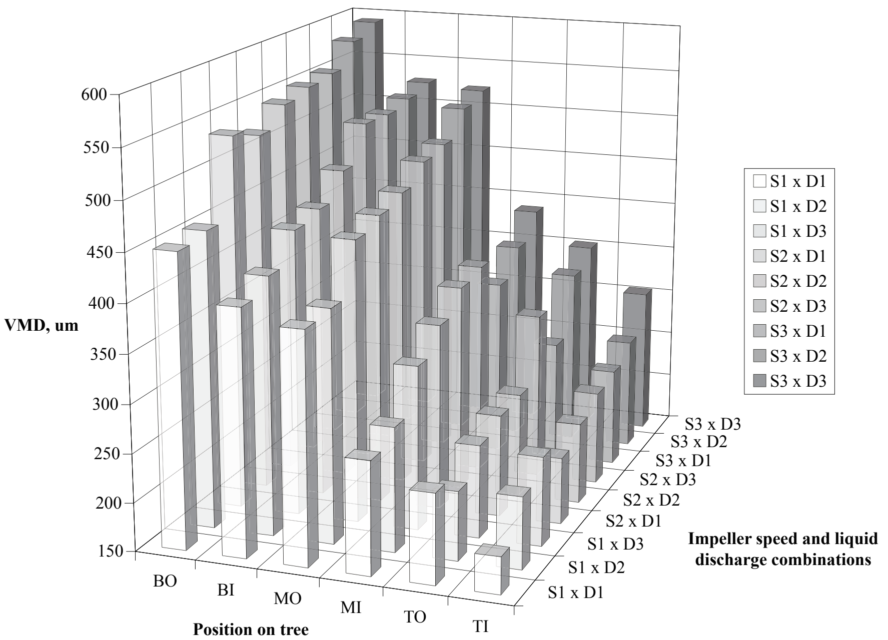

Fig. 1 VMD on upper leaf surface

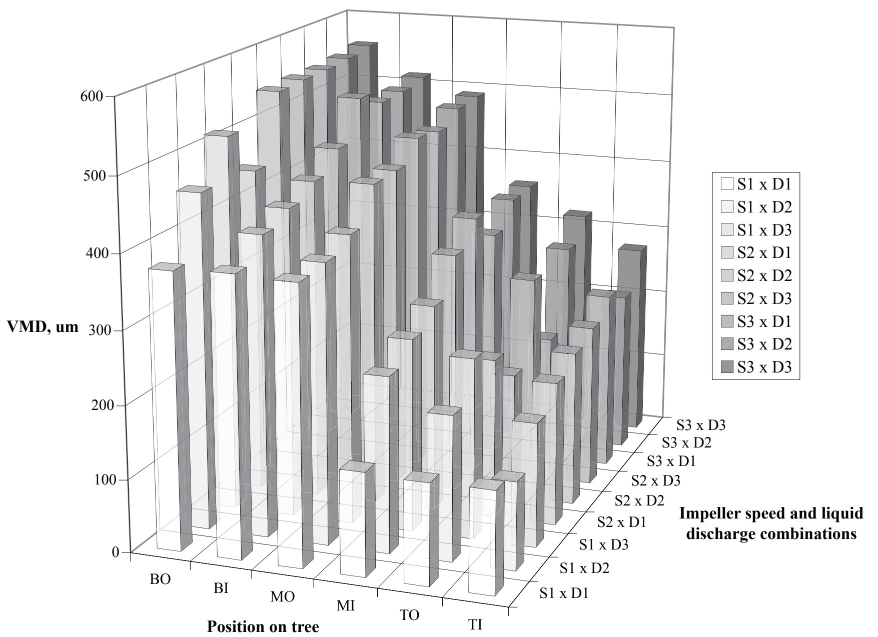

Fig. 2 VMD on lower leaf surface

canopy. Coloured liquid was used for spraying on the tree. Thus, in all 24 sample leaves representing the crown were selected for analysis.

With these design parameters the following were the independent and dependent parameters for field evaluation of the sprayer:

Independent Parameters

1. Impeller speed, rpm (S): 2250, 2500, 2800
2. Liquid discharge, cc/min (D): 3 levels (as per **Table 1**)
3. Leaf surface: Upper, Lower
4. Leaf traverse location: Top, middle, bottom
5. Leaf transverse location: Inner side, outer side in the canopy

Dependent Parameters

1. Droplet density, droplet/sq. cm.
2. Spray VMD, µm

All the samples were analysed for VMD and droplet density using computerised IMAGE PRO ANALYSER.

Table 2 Statistical analysis of VMD date on upper leaf surface for total crown

Position on tree treatment	Bottom outer (BO)	Bottom inner (BI)	Middle outer (MO)	Middle inner (MI)	Top outer (TO)	Top inner (TI)	Mean
S_1 x D_1	450	402	387	266	242	188	322.5
S_1 x D_2	455	416	390	278	221	224	330.7
S_1 x D_3	536	446	442	320	246	242	372.0
S_2 x D_1	524	453	452	344	256	219	374.7
S_2 x D_2	544	479	461	366	258	234	390.3
S_2 x D_3	551	516	480	372	324	247	415.0
S_3 x D_1	555	514	486	336	275	252	403.0
S_3 x D_2	580	520	513	362	336	266	429.5
S_3 x D_3	592	527	522	388	352	304	447.5

CD (5 %): 19.046 CD (1 %): 25.494 CV = 4.22 % MEAN = 387.241 µm

Table 3 Statistical analysis of VMD date on lower leaf surface for total crown

Position on tree treatment	Bottom outer (BO)	Bottom inner (BI)	Middle outer (MO)	Middle inner (MI)	Top outer (TO)	Top inner (TI)	Mean
S_1 x D_1	377	381	378	141	138	139	259.0
S_1 x D_2	459	411	382	240	198	120	301.7
S_1 x D_3	516	426	398	265	248	170	337.2
S_2 x D_1	452	444	447	287	221	198	341.5
S_2 x D_2	546	472	448	336	174	214	365.0
S_2 x D_3	548	527	476	368	287	226	405.3
S_3 x D_1	548	506	469	324	177	249	378.8
S_3 x D_2	551	507	487	357	290	225	402.8
S_3 x D_3	557	514	490	359	320	275	419.2

CD (5 %): 32.5 CD (1 %): 43.5 CV = 7.81 % MEAN = 356.722 µm

Note: S = Speed of impeller, D = Liquid discharge, cc/min
S_1 = 2250 rpm: D_1 = 600 cc/min, D_2 = 700 cc/min, D_3 = 840 cc/min
S_2 = 2500 rpm: D_1 = 750 cc/min, D_2 = 890 cc/min, D_3 = 1120 cc/min
S_3 = 2800 rpm: D_1 = 930 cc/min, D_2 = 1000 cc/min, D_3 = 1380 cc/min

Result and Discussion

Droplet spectrum analysis results of all the samples collected are presented in **Table 2** to **Table 5**. **Table 2** and **Fig. 1** show the variation of spray VMD on upper leaf surface with change in blower speed, liquid discharge rate, leaf traverse and leaf transverse location relative to the sprayer. Maximum value of VMD of 592 µm was obtained with the S_3 x D_3 combination at "bottom-outer" position of the tree canopy. Whereas, minimum VMD was found with the S_1 x D_1 combination at "top-inner" location of the canopy. Observation indicates that VMD increases with increase in speed and discharge rate and decreases with increase in traverse as well as transverse distance from the sprayer outlet. The direct relationship of VMD with speed of blower might be because of the increase in the air discharge rate with increase in blower speed. While the inverse relation with the distance from the outlet of sprayer might be because of the loss of en-

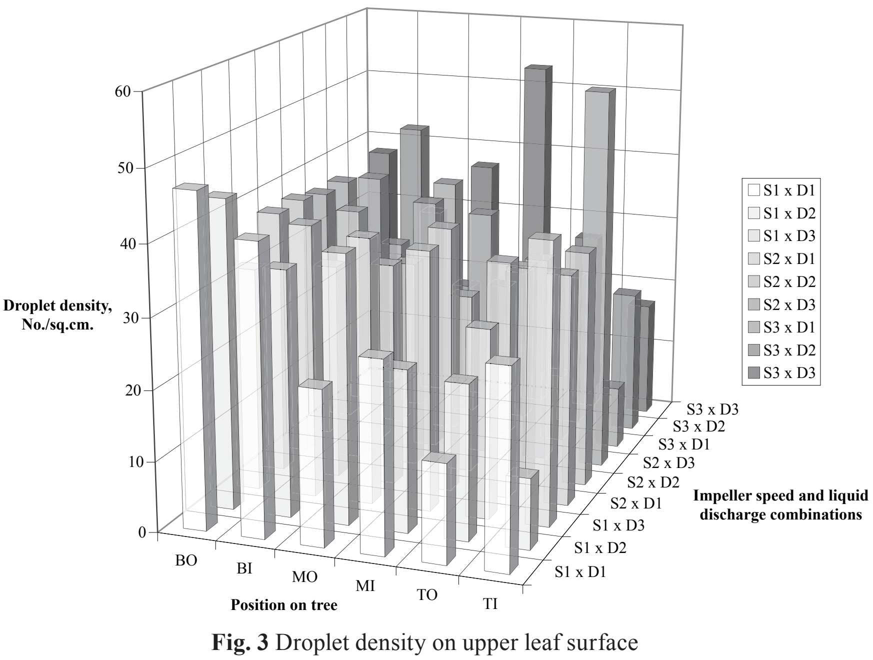

Fig. 3 Droplet density on upper leaf surface

Table 4 Statistical analysis of droplet date on upper leaf surface for total crown

Position on tree treatment	Bottom outer (BO)	Bottom inner (BI)	Middle outer (MO)	Middle inner (MI)	Top outer (TO)	Top inner (TI)	Mean
S_1 x D_1	47	41	22	27	14	28	29.83
S_1 x D_2	44	35	38	23	22	10	28.67
S_1 x D_3	32	39	38	37	27	40	35.50
S_2 x D_1	38	31	32	38	34	33	34.33
S_2 x D_2	38	37	30	26	31	34	32.67
S_2 x D_3	37	40	37	36	30	55	39.16
S_3 x D_1	37	28	38	23	10	09	24.17
S_3 x D_2	26	44	20	23	23	21	26.17
S_3 x D_3	38	29	37	53	27	17	33.50

CD (5 %): NS CD (1 %): NS CV = 27.35 % MEAN = 31.556 nos/sq.cm

Table 5 Statistical analysis of droplet date on lower leaf surface for total crown

Position on tree treatment	Bottom outer (BO)	Bottom inner (BI)	Middle outer (MO)	Middle inner (MI)	Top outer (TO)	Top inner (TI)	Mean
S_1 x D_1	24	34	24	28	31	27	28.00
S_1 x D_2	20	34	32	18	25	06	22.50
S_1 x D_3	11	37	09	04	37	11	18.17
S_2 x D_1	32	33	25	28	22	05	24.17
S_2 x D_2	19	32	28	07	30	43	26.50
S_2 x D_3	23	23	26	16	28	42	26.33
S_3 x D_1	23	19	25	12	19	05	17.17
S_3 x D_2	19	23	12	20	13	11	16.33
S_3 x D_3	24	28	26	25	24	10	22.83

CD (5 %): NS CD (1 %): NS CV = 38.94 % MEAN = 22.444 nos/sq.cm

Note: S = Speed of impeller, D = Liquid discharge, cc/min
S_1 = 2250 rpm: D_1 = 600 cc/min, D_2 = 700 cc/min, D_3 = 840 cc/min
S_2 = 2500 rpm: D_1 = 750 cc/min, D_2 = 890 cc/min, D_3 = 1120 cc/min
S_3 = 2800 rpm: D_1 = 930 cc/min, D_2 = 1000 cc/min, D_3 = 1380 cc/min

ergy due to the obstructions of the branches and leaves and increase in lateral cross section of the air flow. Thus, this decreased energy is only capable of carrying small droplets to the upper canopy of the tree that causes less VMD at the upper locations. Higher VMD values at the bottom portion might be due to more airflow and overlapping of droplets over each other. Considering the effective VMD values mentioned by past research workers (100 to 400 µ m), best results were obtained with the S_1 x D_1 combination with VMD ranging between 188 to 450 µm at "top-inner" and "bottom-outer"position respectively. Similar trend was observed from VMD at lower leaf surface area (**Table 3** and **Fig. 2**). Here the best results were obtained with the S_1 x D_1 combination with VMD ranging between 139 to 377 µ m at "top-inner" and "bottom-outer" position respectively.

Table 4 and **Fig. 3** show the droplet density distribution at the upper leaf surface area. Minimum droplet density of 9 droplet/sq cm was obtained with S_3 x D_1 combination at "top-inner" location. Maximum value of 53 droplet/sq. cm was obtained with S_3 x D_3 at "middle-inner" location of the canopy. Statistical analysis of the data indicates pthat variation with blower speed, liquid discharge rate and traverse and transverse distance is non-significant (Critical Difference value is NS). This might be due to more value of droplet density at the bottom was due to more air flow rate (power) at relatively shorter distance. Whereas more value at upper location of the tree canopy. Thus considering the values of droplet density required for the effective control of pests and disease (15-45 droplets/sq cm) all combinations were suitable. However, considering the lower power and chemical requirement at the S_1 x D_1 combination it was considered as the best combination for effective spraying with droplet density ranging from 14 to 47 droplets/sq. cm. **Table 5** and **Fig. 4** indicate the similar trend with droplet density at lower leaf surface area. Non-significant critical difference indi-

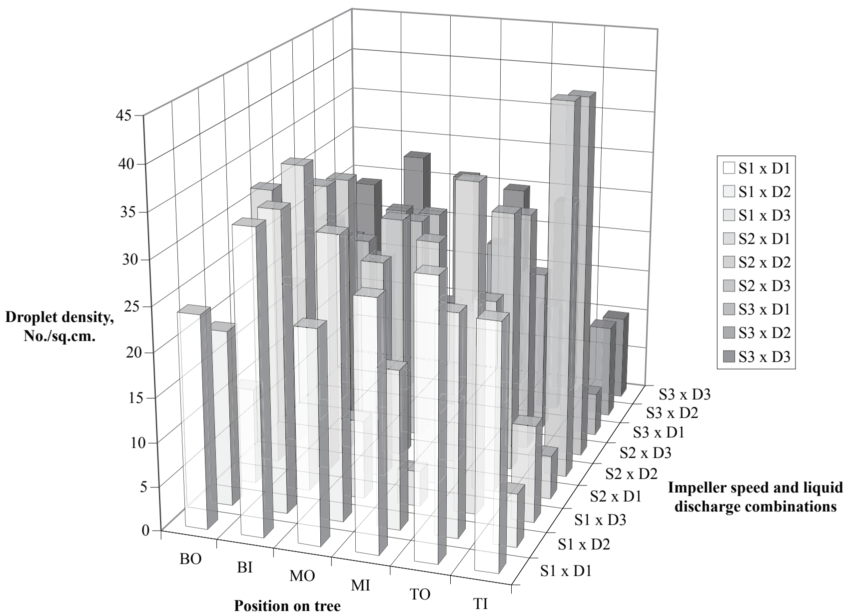

Fig. 4 Droplet density on lower leaf surface

cates that there was no significant difference in the values of droplet density at any combination of speed and liquid discharge rate. Therefore, S_1 x D_1 combination at which droplet density varied between 24 to 38 droplets/sq cm was considered best suitable combination for spraying on mango tree.

Conclusion

On the basis of data collected and statistical analysis following conclusions could be inferred:

• VMD increases with increase in blower speed and liquid discharge rate.

• VMD decreases with increase in transverse as well as traverse distance of leaf from the blower outlet.

• Best results of VMD (188-450 µm) on the upper leaf surface was obtained at S_1 x D_1 combination.

• Best results of VMD (139-377 µm) on the lower leaf surface was obtained at S_1 x D_1 combination.

• There was no significant effect of blower speed, liquid discharge and traverse and transverse distance of leaf from the blower outlet on the droplet density of spray.

• Best results of droplet density (14-7 µm) at upper leaf surface was obtained at S_1 x D_1 combination.

• Best results of droplet density (24-38 µm) at lower leaf surface was obtained at S_1 x D_1 combination.

• The developed blower is suitable for spraying on mango tree at S_1 x D_1 combination with good results both on upper as well as lower leaf surface area.

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Effect of Cone Angle on Droplet Spectrum of Hollow Cone Hydraulic Nozzles

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Abstract

Effective pest and disease control is accomplished with the help of sprayers that have better designed nozzles. The essence of spraying is reduction of spray solution into droplets that is usually achieved by nozzles operating at constant pressure, specific discharge and cone angle. This study was undertaken to determine the effect of cone angle on the droplet spectrum of a hollow cone nozzle by keeping constant operating pressure at 3 kg/cm^2 and discharge of 473 ml/min. Six nozzles with cone angles of 57.66º, 59.0º, 64.4 º, 68.5º, 77.0º and 87.0º were tested. A droplet analyzer analyzed the number of spray droplets. Amongst six nozzles, the spraying performance of a hollow cone nozzle with a cone angle of 68.5º was best. The tests with this nozzle resulted in a useful volume of 3.189 x 10^{-4} cc, a maximum volume mean diameter of 149.99 µm and a maximum droplet density of 636 droplet/sq cm, which provided effective disease control. The uniformity coefficient of this cone angle was 0.955, which is near unity. The second best value for useful volume (2.847 x 10^{-4} cc) and droplet density (617 droplets/sq cm) were for a cone angle of 64.4º which had a uniformity coefficient 0.975. The other cone angles were less effective in comparison with the cone angle of 68.5º.

Introduction

Pest control is of vital importance for successful growth of any crop. The essence of spraying is reduction of spray solution into droplets, which is usually achieved by nozzles. Nozzles are designed to operate at constant pressure for different spray angles ranging from a straight stream to 100 degrees. Spray pattern, droplet spectrum and discharge rate mainly depend upon cone angle where pressure is constant. Byass and Charlton (1968) found that, while operating, nozzle spiral motion is imparted to the liquid in a chamber immediately behind the orifice plate. The angle and number of tangential ports through which the liquid enters, govern the swirl velocity in this chamber. Combination of orifice and swirl can, thus, be arranged to give any desired combination of discharge and cone angle.

Droplets below size 150 µm have insufficient kinetic energy to overcome the surface energy and viscous forces and cannot bounce (Breenskill, 1956). Spray droplets with 500 µm V.M.D. (volume mean diameter) do not provide as good disease control as those with the 100-400 µm (Willson et al., 1963). A model was developed to determine deposition efficiency of 91 and 11 percent for 200 and 20 µm droplets respectively (Miles et. al., 1975).

Droplet size between 140 µm and 200 µm was recommended for spraying most crops. Also droplet density of 20-25 droplets/cm^2 was proven most effective for control of boll weevil insect on cotton (Smith et. al., 1975). For most pests and dis-

Cone angle (degrees)	Orifice diameter (mm)	Swiri plate diameter (mm)
57.66	1.016	0.8890
59.0	0.9652	0.9906
64.4	0.9398	0.9398
68.5	0.9652	0.9652
77.0	0.9906	0.9398
87.0	1.0922	0.8890

Table 1 Specification of nozzles

ease control, 100-200 µm was recommended as optimum droplet size (Plotts, 1976). For reducing drift potential for wind speeds of 1.6 to 11.2 kmph the critical droplet diameter was 150-200 µm (Bode, 1981). For similar nozzles with constant pressure drop, the droplet size increased with nozzle size by the equqtion

D_{vm1}/D_{vm2} = (orifice diameter 1/ orifice diameter 2) $^{2/3}$.

Perry (1984) reported that a shift to a smaller angle nozzle gave slightly larger drops for a given type of nozzle because of the reduced tendency of the liquid sheet that remains to be integrated in a film form.

Droplet spectrum refers to the ranges of the droplet size obtained from the nozzle and is a function of operating pressure and discharge. Usually, finer droplets are associated with the greater discharge, higher pressure and wider cone angle, while coarse droplets are associated with low discharge, low pressure and smaller cone angle. Droplets too small in size may be lost by drift while those too big do not adhere to the target surface resulting in reduced application efficiency. Thus, this study was undertaken with the objectives of fabricating hydraulic nozzles of different cone angles that would have constant discharge at constant pressure; studying the spraying parameters by determining droplet size distribution of the nozzles; and to find the cone angle of the most effective nozzle.

Material and Methods

Six hydraulic hollow cone nozzles with the different cone angles were fabricated by selecting different swirl plate diameters and orifice diameters so as to discharge the liquid spray at a constant rate of 413 ml/min with an operating pressure of 3 kg./cm^2.

The nozzle specifications are given in **Table 1**.

A nozzle patternator was used to measure the cone angle and discharge of nozzles. Operating pressure and height of nozzle above patternator surface were kept constant.

An overhead trolley system was used to simulate spraying operation in the laboratory under controlled conditions of wind velocity, speed of operation, and distance between nozzle and target. In the system, pressure at the nozzle was kept constant by a pneumatic regulator. During the movement of the trolley, droplets of the coloured solution of Methyl Violet Crystal Hydrochloride (concentration - 10 gm in 1000 ml water) were collected on glossy papers from a fixed height of 66.5 cm. The speed of trolley was maintained at 2.4 kmph. The droplets, thus, obtained were studied under a microscope attached to droplet size analyzer manufactured by M/s Flemings Instruments Ltd., England. The numbers of droplets obtained by spraying were counted in the range of 1-250 micron. A psychrometer, hygrometer and anemometer were used to record dry and wet bulb temperature, relative humidity and wind velocity during the experiment.

Results and Discussion

A droplet size analyzer in which numbers of droplets were obtained in various ranges analyzed the number of spray droplets. A computer program was used to calculate the volume of droplets in various ranges and other aspects such as number mean diameter, volume mean diameter, uniformity coefficient and droplet density. The number and size of droplets along with the volume are given in **Table 2** for each nozzle. **Table 3** and **Fig. 1a** and **b** show that a useful volume of 3.189 x 10^{-4} cc was the maximum and occurred for the nozzle having a cone

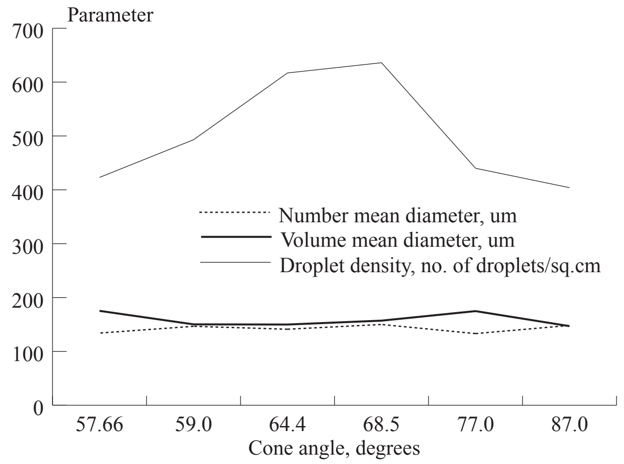

Fig. 1a Spraying parameters of nozzle with different cone angles

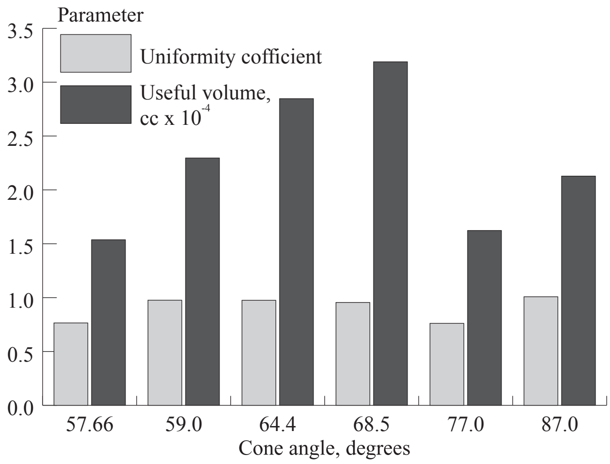

Fig. 1b Spraying parameters of nozzles with different cone angles

angle of 68.5º. This nozzle also had the maximum volume mean diameter of 149.99 µm and the maximum droplet density of 636 drops per sq cm, which provides effective disease control. The value of uniformity coefficient was 0.955 that was near unity. The nozzle of cone angle 64.4º had second best values for useful volume (2.847 x 10^{-4} cc), droplet density (617 drops per sq cm) and uniformity coefficient (0.975). The mean diameter for all nozzles ranged from 146.91 µm to 175.29 µm; the volume mean diameter ranged from 133.06 to 148.20 µ m; the droplet density ranged from 404 to 636 droplets per sq cm; the uniformity coefficient of the nozzles ranged from 0.761 to 1.008; and the useful volume ranged from 1.537 x 10^{-4} to 3.189 x 10^{-4} cc. The study also showed that the orifice size of 0.9652 mm and swirl plate diameter of 0.9652 mm was most efficient as compared to other combinations.

Cone angle (degrees)	Number mean diameter (µm)	Volume mean diameter (µm)	Droplet density (no. of droplets/sq.cm)	Uniformity coefficient	Useful volume (cc)
57.66	175.29	134.05	423	0.765	1.537 x 10^{-4}
59.0	150.23	146.61	493	0.976	2.296 x 10^{-4}
64.4	149.91	141.18	617	0.975	2.847 x 10^{-4}
68.5	157.12	149.99	636	0.955	3.189 x 10^{-4}
77.0	174.81	133.06	440	0.761	1.623 x 10^{-4}
87.0	146.91	148.20	404	1.008	2.128 x 10^{-4}

Table 3 Spraying parameters of hollow cone nozzles with different nozzle angles

Conclusion

It was concluded from the experimental results that spraying performance of the hydraulic hollow cone nozzle was more effective for spray angle 68.5º at a constant pressure of 3 kg/sq. cm and discharge rate of 473 ml/min.

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Table 2 Droplet spectrum study of hollow cone nozzles

Droplet size range (µm)	Average droplet size (µm)	Actural droplet diameter (µm)	Cone angle 57.66º		59.0º		64.4º		68.5º		77.0º		87.0º	
			No.of drop-lets	Volume of droplets (cc)	No.of drop-lets	Volume of droplets (cc)	No.of drop-lets	Volume of droplets (cc)	No.of drop-lets	Volume of droplets (cc)	No.of drop-lets	Volume of droplets (cc)	No.of drop-lets	Volume of droplets (cc)
1-25	12.5	08.439	1	3.146 x 10^{-10}	4	1.258 x 10^{-9}	6	1.887 x 10^{-9}	3	9.439 x 10^{-10}	0	0	0	0
26-50	37.5	25.300	4	3.390 x 10^{-8}	9	7.627 x 10^{-8}	8	6.780 x 10^{-8}	11	9.322 x 10^{-8}	3	2.542 x 10^{-8}	1	8.475 x 10^{-9}
51-75	62.5	42.200	9	3.539 x 10^{-7}	16	6.292 x 10^{-7}	14	5.506 x 10^{-7}	15	5.899 x 10^{-7}	9	3.539 x 10^{-7}	5	1.966 x 10^{-7}
76-100	87.5	59.100	14	1.512 x 10^{-6}	21	2.268 x 10^{-6}	19	2.052 x 10^{-6}	25	2.700 x 10^{-6}	15	1.620 x 10^{-6}	10	1.080 x 10^{-6}
101-125	112.5	75.960	19	4.357 x 10^{-6}	26	5.963 x 10^{-6}	34	7.798 x 10^{-6}	40	9.174 x 10^{-6}	20	4.587 x 10^{-6}	18	4.128 x 10^{-6}
126-150	137.5	92.839	24	1.005 x 10^{-5}	31	1.298 x 10^{-5}	43	1.800 x 10^{-5}	45	1.884 x 10^{-5}	21	8.794 x 10^{-6}	29	1.214 x 10^{-5}
151-175	162.5	109.700	27	1.865 x 10^{-5}	32	2.210 x 10^{-5}	47	3.247 x 10^{-5}	55	3.799 x 10^{-5}	24	1.658 x 10^{-5}	31	2.141 x 10^{-5}
176-200	187.5	126.600	28	2.973 x 10^{-5}	39	4.141 x 10^{-5}	52	5.521 x 10^{-5}	54	5.734 x 10^{-5}	27	2.867 x 10^{-5}	34	3.610 x 10^{-5}
201-225	212.5	143.500	29	4.484 x 10^{-5}	39	6.031 x 10^{-5}	52	8.041 x 10^{-5}	58	8.969 x 10^{-5}	31	4.793 x 10^{-5}	39	6.031 x 10^{-5}
266-250	237.5	160.400	28	6.047 x 10^{-5}	49	1.058 x 10^{-4}	54	1.166 x 10^{-4}	62	1.339 x 10^{-4}	32	6.911 x 10^{-5}	44	9.502 x 10^{-5}
>250	262.5	177.300	240	7.000 x 10^{-4}	227	6.621 x 10^{-4}	288	8.400 x 10^{-4}	268	7.816 x 10^{-4}	258	7.525 x 10^{-4}	193	5.629 x 10^{-4}

Dry bulb temperature: 30 ºC, Wet bulb temperature: 27 ºC, Speed: 2.4 km/hr, Height of nozzles from target: 66.5 cm
No. of replication: 3, Operating pressure: 3 kg/cm^2

Feasibility of Using Yield Monitors for the Development of Soil Management Maps

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Abstract

The advent of yield monitors provides an unprecedented opportunity to investigate the feasibility of using soil-mapping units for field scale management of crop yields. The objective of the study was to study the feasibility of using crop yield monitor data delineating different soil mapping units within fields cropped to corn, wheat and soybean. Pairwise yield comparisons, were made between yields, obtained by yield monitors in different land areas of the fields delineated by soil mapping units. Significant differences were found for mean crop yields within land areas delineated by soil mapping units for all three crops but were not significant when one standard deviation of mean were considered. These significant differences suggested that the crop yields are distributed uniformly with localized variability over the field. The lack of adequate replications of soil mapping units within a field made it difficult to evaluate soil type differences.

Introduction

Yield monitors provide detailed crop yield information as a field is harvested. Without this information, it has been difficult to document the actual yield of a crop in all parts of a field. With such information, it should now be possible to determine the productivity of different land areas enclosed by soil mapping unit delineation. An understanding of the patterns of soil and crop yield variability is important for implementing variable rate fertilizer applications because yield goals influence fertilizer recommendations. There have been several attempts to relate crop yields to soil types (Karlen et al., 1990; Carr et al., 1991; Colvin et al., 1995; Wibawa et al., 1993; Sadler et al., 1998; Steinwand et al 1996; Lamb et al., 1997; Lark and Stafford, 1996) but the conclusions have been contradictory. Farm fields can be divided into land areas based on yield monitor-mapping unit delineation. If different areas within a field have a different yield potential, it should be possible to manage them individually or group them into manageable areas (Radhakrishnan, 1999). The objective of this study was to determine the feasibility of using soil mapping units large numbers of yield data obtained from the yield monitor for the development of crop yield management maps by testing for differences between land areas delineated by mapping units in three fields cropped to corn, soybean and wheat.

Materials and Methods

Yield Monitor and its Working

Yield monitor (Ag Leader Technology™ Yield Monitor 2000™) data of corn, wheat and soybean for 1996 were collected from private producer fields in the Chester River Watershed in Kent County, Maryland, USA and subsequently used in the analyzes. Ag Leader sells the most widely-used grain yield monitoring technology which is available for nearly all combines made in the last 25 years. It can monitor the wide range of crops that a combine can harvest, including small grains, corn, soybeans, rice, and even grass seed (**Fig 1**). It will display and record yield, moisture, combine speed, grain flow, acres, distance, wet bushels, dry bushels, and acres per hour. It organizes data by year, farm, field, grain, and load for easy identification. Data can be transferred to a computer to print a summary of all fields. Adding GPS and memory card will automatically record the instantaneous information to print yield and moisture maps. As a mapping system, it performs all the monitoring features above, plus creates an on-screen field map and allow spot marking of rocks, holes, etc. to show up on the yield map. By itself, the Yield Monitor is a valuable tool to give reliable yield information quickly (Pfeiffer et al, 1993) and, also, a harvest summary at the end of the season, enabling the farmers to respond to farming operation in a precision way (Stafford et al, 1991).

The 1:15,840 soil survey maps (USDA, 1981) were digitized and the base map, with associated attributes, was provided by the US Fish and Wildlife Service. A methodology was developed to extract crop yield information on the number of data values, minimum yield, maximum yield, mean, variance and standard deviation from entire producers' fields. Although the mean and standard deviations can be used as indicators of crop yields and their relative variability, aggregate pairwise comparisons between and among the different mapping units was not possible because of the nature of variances involved. The entire yield monitor data was used in t-tests to determine differences between mean crop yields of land areas delineated by soil mapping units. The Arc-Info point coverage was overlaid with the boundary soils coverage and all the yield values that fell within individual soil mapping unit polygon boundaries were extracted and summarized. All the yield values from different mapping units obtained from this overlay procedure in Arc-Info were used in the t-test procedure. A simple statistical program was written in SAS for t-tests to compare yield values to test the null hypothesis that there are no differences in mean yields between land areas within the fields delineated by soil mapping unit polygons.

Study Site and Soil Types

The fields of corn (53 hectares), soybean (18.2 hectares) and wheat (25.5 hectares) are located on the northern boundary of the Chester River Watershed in Kent county, Maryland, USA. The soil mapping units as delineated by soil survey were: Mattapex- Matapeake- Butlertown silt loams, 2-5 % slopes (MxA), Matapeake silt loams, 2-5 % slopes (MnB), Matapeake silt-loam, 5-10 % slopes (MnC2) and Sassafras loam, 2-5 % slopes (SfB) for the corn field. For the soybean field, the mapping units were: Coltsneck gravelly loam, 5-10 % slopes (CgC3), MxA, and Mattapex silt loam, 0-2 % slopes (MtA). For the wheat field the mapping units were: Sassafras loam, 2-5 % slopes (SfB), Mattapex-Matapeake-Butlertown silt loams, 2-5 % slopes (MxB), MnB, Butlertown siltloam, 5-10 % slopes (BuC2), SfB and MxA (USDA, 1981).

Results and Discussions

Pair-wise comparisons of crop yields within map unit delineation for 56, 34 and 29 fields for corn, soybean and wheat respectively, were analyzed but for the sake of brevity summarized results from one field for each crop is presented (**Tables 1**, **2**,and **3**) and discussed. Pair-wise comparisons of mean corn yields of land areas delineated by mapping unit polygons, indicated that there were significant differences in these mean yields as detailed elsewhere (Radhakrishnan, 1999). The variability associated with the Bs map unit was high (as evidenced by the standard deviation) due to a fewer number of samples compared to the other mapping units. With a large number of samples for the other mapping units the variability was reduced. There were significant differences in wheat map unit means except for mapping unit MnB and mapping unit MxA which are not significantly different. The relative variability as evidenced by the standard deviations was relatively similar for all the mapping units. Although slope and erosion differences existed between these two map units, it is not reflected in the differences in crop yields. There are some definite conclusions than can be drawn.

As the spatial area of sampling and the number of samples increase, the range of yield values within land areas delineated mapping units also increase contributing to significant differences. However the mean crop yields within the land areas varied greatly as evidenced by the standard deviations for all the three crops (**Tables 1** to **3**). Based on mean yields the differences in

Fig. 1 Working of yield monitor mounted on a combine during wheat harvest

yield between land areas enclosed by soil mapping unit polygons were less than 0.4 tons/hectare for corn with the exception of the Bs mapping unit. These differences were less than 0.2 tons/hectare for wheat. The differences in mean crop yields of land areas enclosed by soil mapping units for soybean were less than 0.1t/ hectare except for the differences between CgD3 and CgC3, and CgD3 and SfB. Yields seemed to be fairly uniformly distributed with fairly uniform quantities of variance associated with the yields. As the number of data values increase the distribution of these values tend to approach normality and the mean differences between these data come closer and closer together such that the differences based on means alone become small. However, the differences in crop yields between land areas enclosed by soil mapping unit polygons are not significant based on one standard deviation overlap. This was also reported by Colvin et al. (1995).

The minimum resolvable detail at the scale of the soil survey in a mapping unit is one hectare. Virtually every soil mapping unit delineation includes areas of soil components or miscellaneous areas (inclusions) that are not identified in the name of the mapping units. Many of these components are too small to be identified with existing field methods. Inclusions reduce the homogeneity of the mapping units and could contribute to the differences seen. The results from this study suggest that crop yield variation can be partly explained by differences in soil mapping units at the 1:15,840 scale, but managing individual soils rather than fields does not appear feasible with the current levels of soil information. Though, the results from this study suggest that there are significant differences in yields between land areas delineated by mapping units at the 1:15,840 scale, based on the data for 1996, which happened to be a "near normal" rainfall year, the relationships may not be the same in a drought year.

Implications of Yield Monitor Technology for Precision Farming in Developing Countries in Asia, Africa and Latin America

Mounting populations, improving diets due to economic development, and increasing urbanization are expected to further enhance demand for more and superior quality food in the Asia and Africa region. Deteriorating environmental quality, declining input response of major crops, and a widening gap between the potential and realized farm yields are main points of concern in current Asian agriculture. Adoption of precision farming through practices such as optimal application of inputs depending on spatial and temporal variability of crop yields and soil properties is increasingly recognized as a valuable approach to sustain yields and improve environmental quality. Because of wide diversity in crops and cropping systems, farm sizes and socio-economic conditions, Asian farming systems present both opportunities and obstacles for adoption of precision farming.

It is well known that sustainable agricultural development can happen only if the natural resource base upon which it depends is prudently managed. However, in Asia and the Pacific region, yield increases in this region have been achieved at considerable expense to its resource base and largely by means of excessive and indiscriminate use of external inputs: irrigation, seeds, fertilizer, pesticides, etc. High rates of aquifer depletion, pest and disease incidence, environmental pollution, soil erosion, and reduced biodiversity are, therefore, rampant. For instance, soil erosion in this region due to water and wind exceeds the natural soil formation by 30-40 fold (FAO, 1993). The problem of water quality deterioration is also serious. Pollution of drinking water in tobacco and rice ecosystems of Malaysia (Ahmad et al., 1996) and of groundwater near vegetable fields in Japan (Nishio, 1998) are just two examples.

Precision Farming (PF) technologies have been developed in countries where farm socio-economic conditions are much different than in Asia. It must be noted, however, that even under subsistence farming, several decisions (application rates of seeds, fertilizers and other inputs) have to be made for optimizing yields and income. As PF technologies assist farmers in improved decision making, and have the

Table 1 Differences in corn yields (t/ha) between original yield monitor date and land areas enclosed by different mapping units

Map unit	Mean corn yield	MnB 0.52	MnC2 0.35	MxB 0.42	SfB 0.53
Bs	3.80	4.00	3.21	3.80	4.49
MnB	0.52	-	0.38	0.26	0.42
MnC2	0.35	-	-	0.58	1.27
MxB	0.42	-	-	-	0.69

The number of observations (N) for mapping units for Bs = 262, MnB = 22851, MnC2 = 1104, MxB = 13056 and SfB = 1057.

Table 2 Differences in wheat yields (t/ha) between original yield monitor date and land areas enclosed by different mapping units

Map unit	Mean wheat yield	SfB 0.71	MxA 0.89	BuC2 0.71	MxB 0.77
MnB	3.70	0.27	0.62	0.45	0.18
SfB	0.71	-	0.32	0.12	0.08
MxA	0.89	-	-	0.44	0.22
BuC2	0.71	-	-	-	0.21

The number of observations (N) for mapping units for MnB = 695, SfB = 1404, MxA = 386, BuC2 = 373 and MxB = 9298.

Table 3 Differences in soybean yields (t/ha) between original yield monitor date and land areas enclosed by different mapping units

Map unit	Mean soybean yield	CgD3 0.57	MtA 0.41	CgC3 0.46	SfB 0.51
MxA	0.46	0.28	0.07	0.57	0.30
CgD3	0.57	-	0.35	0.85	0.64
MtA	0.41	-	-	0.50	0.28
CgC3	0.46	-	-	-	0.21

The number of observations (N) for mapping units for MxA = 5715, CgD3 = 20, MtA = 2135, CgC3 = 952 and SfB = 818.

potential to reduce or remove the effects of limiting factors on the farm, a convincing case can be made on their suitability to Asian conditions.

Conclusions

In this study the differences and similarities in crop yields obtained from yield monitors and that delineated by soil mapping unit polygons were analyzed. Significant differences occurred in crop yields between land areas delineated by mapping units when large numbers of crop yield values from the entire yield monitor files were used in the analysis. Although significant differences in mean crop yields between mapping units have been obtained, the lack of adequate information in the soil survey data and the inherent variability associated with crop yields and soil properties, make it difficult to directly support the use of soil mapping units in developing crop yield management maps. But it is adjudged that there is great potential for using yield monitor to develop field management maps when soil information is available in necessary detail.

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Improving Whole Kernel Recovery in Cashew Nut Processing Specific to Nigeria Nuts

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Abstract

The cashew industry plays an important role in Indian economy. About 70 percent of total raw cashew nut exported from Nigeria goes to India for processing. Kernel damage (16 percent) in de-shelling operation is primarily due to irregular shape of the nut and wide variation in nut size. Raw nut exposed to steam for 33 minutes maintained at 100 PSI with subsequent cooling for 18 hours was found to give optimum results at shelling stage. Exposing the kernels to hot air at 70 ºC for 6 hours with a cooling period of 24 hours eased the peeling process and resulted in a high percent of whole kernels with minimal scorching and a low percent of difficult to peel kernels. Rate of moisture removal during kernel drying is faster during the first six hours affected by the free moisture in the kernel.

Introduction

Organized cashew processing originated and developed in India. Presently, the Indian system of cashew nut processing is considered to be an effective and economical method worldwide. Over 1295 factories with annual processing capacity of 1.0 million tones constitute cashew-processing sector in India (Abdul Salaam, 1999). About 0.08 million MT of cashew kernels were exported in 2000-2001 and earned a foreign exchange of Rs18.8 million (Anonymous, 2001). Two-thirds of the total industries in India follow steam boiling and cashew nut processing which involves material separation in the unit operations of nut conditioning, shelling, kernel drying, peeling and packaging with an ultimate aim of recovering white whole kernels. Raw nuts are imported from various countries to supplement indigenous production and 79 percent of total export from Nigeria goes to India. Difficulty in peeling without breakage is one of the serious problems in processing Nigerian nuts (Anonymous, 2001). End product quality is predominantly a function of raw nuts, processing technique and plant management, which decisively influence financial results. The potential loss could be due to

- Inferior raw nut quality in the line of processing
- Improper nut conditioning
- Incorrect manipulation of nuts during de-shelling
- Ineffective kernel drying technique

Considering the mentioned causes, an investigation was pursued to optimize various technical parameters in order to improve the whole kernel recovery and ease kernel peeling. The problem was attempted in two phases; initially the technical parameters related to nut conditioning were optimized to ensure better whole kernel recovery at shelling stage. In the second phase, in order to maintain optimum nut-conditioning parameters, the kernel drier conditions were optimized to ease peeling and improve whole kernel yield without scorching.

Materials and Methods

Physical Dimension and Moisture Content

Raw cashew nuts of Nigeria origin were collected from the local industry and cleaned from adhering dirt and stones. In order to determine the proportion of nuts based on the size and mass, a sample of 100 nuts were collected randomly and its principal axis dimensions of length, width and thickness were measured with an electronic micrometer which had an accuracy of 0.01 mm. Because of the irregular shape of the nut, width and thickness were measured perpendicular to major axis (Balsubramanian, 2001). A precision electronic balance reading 0.01 g (LC) was used to obtain individual nut weight. The initial moisture content of the raw nut sample was determined using toluene distillation method and the values were expressed in dry basis.

Optimizing Steam Exposure Period

Raw nuts were conditioned by exposing to steam in the baby boiler. The baby boiler consisted of a cylindrical drum with a hopper on the top to feed the nuts. Steam generated in a boiler was let into the nut chamber (320 kg nut capacity) at 100 PSI. After saturation, steam pressure droped to 80 PSI and care was taken to maintain the pressure such that CNSL does not ooze out from nut. Nuts were subjected to various times of steam exposure; 32, 33, 34, 35 and 35 minutes in different batches. Afterwards, the nuts were cooled in an ambient environment for 14, 16, 18, 20, 22, 24 hours in thin layers. Three samples of 5 kg weight were drawn randomly from each batch and deshelled using hand-cum-pedal operated sheller to extract the kernels. The shelled kernels were sorted into wholes, broken and rejects based on the specifications (Shivanna, 1973) and their weights were noted.

The extracted kernels were subjected to hot air drying in a borma drier to enable removal of its brown skin (testa) without damage. Borma drier is a cabinet type drier heated by cashew shell at the bottom. Kernels were spread on a tray with a wire mesh bottom and loaded inside the drying chamber. Heat radiated from the bottom and sides through iron plates to the kernel (Sankaran Nambhudiri, 1972). Primarily the kernels were subjected to hot air maintained at 90 ºC for 8 hours and then air temperature was reduced to 80 ºC gradually for next 12 hours. After drying, kernels were air cured for 14 to 24 hours. During cooling, random samples were drawn at two hour intervals from each batch and its adhering testa was removed manually. Finally, peeled kernels were segregated into wholes, broken, rejects and difficult to peel kernels and weighted. The quality index was calculated as shown below

Quality index = $\sum K_i P_j$...............(1)

Where K is kernel grade (i, j = whole/broken/difficult to peel kernels) after peeling process; P is the average price of respective grades

The values were fit to a second order polynomial equation and, by equating its derivatives to zero, the optimum values were obtained.

Wholes to broken kernel ratio (WBR) and the difficult to peel kernels (DPK) are the primary indicators to assess the qualitative efficiency of kernel out put and they are calculated as follows,

WBR = Q_w / Q_b...........................(2)

Where WBR is wholes to broken ratio; Q_w is the quantity of whole kernels obtained in kg and Q_b is the quantity of broken kernels obtained in kg.

Difficult to peel kernels are the ones with more skin adherence and difficult to peel off by the application of extra pressure. The DTP kernels are calculated as

DPK =(Q_{dp}/ Q_k) x 100..............(3)

Where DPK is the difficult to peel kernels in %; Q_{dp} is the quantity of difficult to peel kernels in kg and Q_k is the quantity of kernels obtained in kg.

Optimizing Kernel Drying

In order to optimize the technical parameters related to kernel drying, which are hot air temperature, kernel exposure period and kernel cooling period, an electrically operated cross flow drier (tray drying system

Table 1 Comparison of stage wise kernel recovery in processing goa and Nigeria origin cashew nuts

Particulars	Goa origin		Nigeria origin	
	Quantity (kg)	%	Quantity (kg)	%
Raw nut processed	3,500		3,500	
Impurities	13.3	0.4	17.8	0.5
Spoiled	24.8	0.7	58.6	1.7
RN - Steam boiled	3,461.9	98.9	3,423.6	97.8
Shelling				
Whole kernels	997.5	28.81	928.4	26.8
Broken	35	1.01	69.1	2.0
Rejects	3.2	0.1	5.4	0.2
Shelling recovery	1,032.5	29.8	997.5	29.1
Kernel drying				
Wholes	942.4		890.3	
Broken	32.9		67.4	
Peeling				
Wholes	693.2	67.1	577.7	57.9
Broken	165.9	16.1	208.9	20.9
Difficult to peel	0.9	0.1	22.8	2.3
Peel	103	10.0	103.9	10.4
Rejects	12.2	1.2	43.2	4.3
Grading				
White wholes	494.1	47.9	209.9	21.0
Scorched wholes	93.9	9.1	134.6	13.5
Dessert wholes	56.6	5.5	101.4	10.2
Others wholes	40.7	3.9	61.8	6.2
White broken	98.7	9.6	87.8	8.8
Scorched broken	31.3	3.0	113.4	11.4
Dessert broken	42.1	4.1	75.9	7.6

Values are average of 5 sets of processing nuts at industrial level

Table 2 Physical dimensions of Nigeria nuts

Sl. No.	Length (mm)	Width (mm)	Thickness (mm)	Weight (gm)	Volume (cm^3)	Density (gm/cm^3)
Minimum	19.55	18.02	12.01	2.10	3.00	0.64
Maximum	33.16	28.40	18.69	7.70	7.50	1.23
Average	27.74	22.02	15.81	4.43	4.25	1.04
Correlation coefficient	0.76	0.77	0.57	1.00	0.93	0.52
Standard deviation	2.41	1.96	1.48	1.08	0.89	0.11

Table 3 Effect of steam exposure and cooling period on WBR in shelling

Nut cooling duration (hrs)	Steaming duration (minutes)				
	32	33	34	35	36
14	15.75	20.00	17.80	10.45	9.88
15	16.61	19.38	18.67	11.33	10.88
16	16.96	21.11	20.67	10.58	11.45
17	15.60	19.37	19.79	12.46	12.44
18	15.60	20.44	19.18	11.18	13.38
19	13.48	23.00	21.18	11.07	11.86
20	13.38	21.41	19.37	10.97	13.76
21	14.92	22.12	19.25	-	15.48
22	14.46	21.65	18.95	-	-
23	10.32	-	20.44	-	-
Average	14.71	20.94	19.53	11.15	12.39

- model) was used. Initially, the raw nuts were subjected to steam pressure of 100 PSI for 33 minutes and air cured for 18 hours in the ambient environment. The conditioned nuts were de-shelled using hand-cum-pedal operated sheller to extract whole kernels. The whole kernels were separated and subjected to hot air in a cross flow drier maintained at hot air temperature of 70 ºC, 80 ºC, 90 ºC and 100 ºC in separate batches. The various kernel drying periods at different air temperatures were 6, 8, 10 and 12 hours. After drying, kernels were air cured for 14 to 24 hours and, at regular intervals of two hours, random samples were drawn from each batch and its adhering testa was removed manually. All the experiments were replicated three times and average values were taken for analysis. Peeled kernels were segregated into wholes, broken, rejects, and difficult to peel kernels and their respective weight were taken for analysis. During peeling operation, the ease of peeling and colour of the kernels were observed for every sample to evaluate the effect of various technical parameters. The kernel quality indicators were calculated and the optimum values were determined as explained earlier.

Results and Discussion

The comparison of cashew kernel recovery at various stages of processing of Nigeria and India (Goa) origin is given in **Table 1**. In spite of same shelling recovery, the variation in the proportion of whole and broken kernels at the end of shelling clearly indicates that the nuts were highly irregular in shape and size, posing a problem in manipulating the nut while extracting kernels using the semi-mechanized de-sheller. The kernel proportion at the end of peeling operation clearly indicates low whole kernel recovery (56 percent) for the Nigerian nuts, which is 16.5 percent lower than Indian nuts. In addition, higher values of scorched kernel (33.2 percent) and difficult to peel kernel (2.2 percent) for Nigerian nuts showed the impact of the parameter values in the processing line. At the end, the broken kernels amounted to 25.9 percent

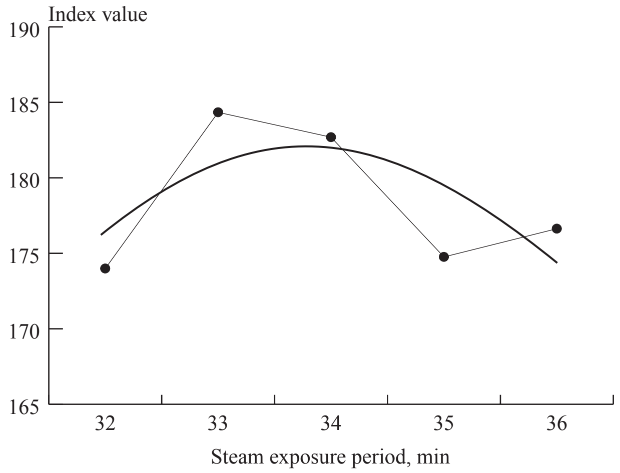

Fig. 1a Optimizing steaming period for cashew nuts of Nigeria

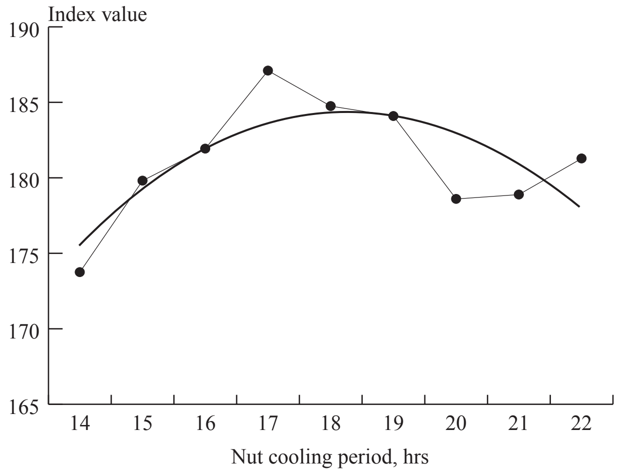

Fig. 1b Optimizing cooling period for cashew nuts of Nigeria

of kernel recovered in shelling, representing improper kernel drying technique and method of peeling.

The minimum, maximum, average and standard deviations of the principal axes of Nigeria nuts are given in **Table 2**. The poor correlation coefficients among length, width, thickness and weight of the nut infer wide distribution of nuts based on size. The average weight of nuts is 4.5 g, which is normally categorized between small to medium quality nuts.

The moisture content of the raw nut samples was found to be in the range of 4.1 to 8.7 percent d.b. confirming that the nuts were well dried before supplying to processing line. Since the raw nuts were imported and stored under high temperature and low humidity environment; that is, during summer, the natural phenomena of nuts attaining equilibrium with environment took place by loosing moisture.

Optimizing Nut Conditioning Parameters

Raw nuts were exposed to steam and, subsequently, cooled to make the nut hard and brittle for opening to extract the whole kernel. During steaming, moisture infused into the nut and distributed uniformly over the nut. When it was subjected to air-cooling after steaming, the nut lost its moisture gradually enabling the testa to loosen from the inner layer of nut (endocarp). Therefore, steam pressure and cooling period were shown to be the critical parameters to be optimized in relation to nut conditioning.

It is evident from **Table 3** that a higher whole kernel recovery (> 18 percent) occured at 33 and 34 minutes of steam exposure than at the other treatments of 32, 35 and 36 minutes of steaming. When the steamed nuts were cooled for 19 hours, a high value of WBR (23.0) was obtained for 33 minutes of steaming.

The average values of WBR (20.9) for 33 minutes of steam duration, at the various cooling periods indicated that this treatment yielded better results during the shelling operation. Less variation was observed with respect to cooling period in terms of WBR indicating that the effect of nut cooling time was not significant. The average ambient temperature and relative humidity during the experimental period were 31.1 ºC and 89.5 percent respectively.

Regression equations for the kernel output after peeling operation at different steam exposure and nut-cooling periods are given in **Table 4**. By optimization technique, it was found that the optimum value of kernel out put was obtained for the nuts subjected to 33 minutes steaming and 18 hours cooling (**Fig. 2**). The proportions of wholes, broken and difficult to peel kernels at the end of peeling was not encouraging for the nuts treated at 32, 35 and 36 minutes.

Optimizing Kernel Drying Parameters

The kernel moisture loss during the drying process subjected to the various air temperatures and cool-

Table 4 Regression equation and optimizing nut conditioning parameters for Nigeria origin

Steam duration	Regression equation	Y
32	Y = -0.2091x2 + 1.7161x + 170.47	173.99
33	Y = -0.4739x2 + 5.0334x + 170.97	184.34
34	Y = -0.3529x2 + 3.0023x + 176.3	182.69
35	Y = -0.313x2 + 1.6736x + 172.52	174.76
36	Y = -0.0669x2 - 0.0747x + 176.61	176.63
Optimum (33 min)	Y = -0.1379x2 + 2.2101x + 168.26	177.12
Optimum (18 hrs)	Y = -0.4739x2 + 5.0334x + 170.97	184.34

Table 5 Quality index for the kernel output in optimizing kernel drying

Exposure period (hrs)	Nut cooling period (hrs)	Hot air temperature ºC			
		70	80	90	100
6	14	202.80	225.67	247.35	235.56
	16	219.29	207.54	248.19	235.25
	18	197.39	219.60	241.61	231.47
	20	225.88	216.74	240.69	231.41
	22	225.63	212.70	244.60	239.37
	24	220.10	203.55	244.26	237.84
8	14	195.76	226.07	248.32	228.93
	16	209.27	225.58	244.45	235.19
	18	208.42	212.34	245.26	227.69
	20	226.28	197.37	240.86	231.26
	22	221.88	202.72	245.72	242.80
	24	216.27	210.45	241.45	227.54
10	14	203.13	216.52	246.11	231.83
	16	227.19	210.45	245.80	233.43
	18	213.88	221.10	241.95	231.75
	20	212.61	204.16	240.36	229.92
	22	221.95	211.47	249.76	237.23
	24	212.43	199.25	241.08	236.93
12	14	212.04	214.23	247.12	231.62
	16	214.44	235.84	241.17	224.05
	18	210.42	217.14	246.18	225.83
	20	201.15	200.69	240.31	243.22
	22	216.53	213.31	240.67	236.42

Index values were calculated based on average price values of whole, broken and difficult to peel kernel

Table 6 Regression equation and optimizing kernel drying parameter for cashew nuts of Nigeria origin

Temp (ºC)	Nut exposure period (hrs)	Regression equation	Y
70	6	**Y = -0.4199x2 + 6.7679x + 197.86**	**225.13**
	8	Y = -1.9609x2 + 18.247x + 178.86	221.31
	10	Y = -1.3802x2 + 10.504x + 199.37	219.36
	12	Y = 2.7397x2 - 16.114x + 229.62	205.93
80	6	Y = -0.348x2 - 0.364x + 220.85	220.95
	8	Y = 2.0612x2 - 19.047x + 247.82	203.82
	10	Y = -0.7878x2 + 2.6519x + 213.16	215.39
	12	Y = 0.8473x2 - 7.6008x + 230.51	211.09
90	6	Y = 0.6433x2 - 5.2778x + 253.16	242.33
	8	Y = 0.2531x2 - 2.7698x + 250.2	242.62
	10	Y = 0.1983x2 - 1.813x + 247.51	243.37
	12	Y = -0.147x2 - 0.6574x + 246.57	247.30
100	6	Y = 0.7103x2 - 4.3026x + 239.48	232.96
	8	Y = -0.5613x2 + 4.4855x + 225.05	234.01
	10	Y = 0.4725x2 - 2.3051x + 234.42	231.61
	12	Y = -0.2442x2 + 3.4617x + 223.94	236.21
70		**Y = -2.4018x2 + 6.0522x + 220.81**	**224.62**
80		Y = 3.2051x2 - 17.826x + 233.34	208.55
90		Y = 0.9129x2 - 2.9991x + 244.56	242.10
100		Y = 0.8881x2 - 3.7077x + 236.31	232.44
Optimized (70 ºC)		**Y = 1.603x2 - 2.3155x + 220.69**	**219.85**

ing periods is given in **Fig. 2**. A significant effect was observed during the initial period of drying up to 6 hours. Rapid rate of moisture loss in the initial phase may have resulted from loss of free moisture. The mechanism of moisture diffusion is greatly influenced by the temperature, which is evident from the faster removal of moisture at higher temperature (90 ºC and 100 ºC). As the drying progresses, the diffusion of bound moisture has taken place and less variation in rate of moisture loss with respect to temperature is observed after 6 hours.

When the kernels were subjected to temperatures of 90 ºC and 100 º C, discolouration of kernels was noticed. This could be due to the effect of higher temperature on the volatile compounds present in the kernels and the kernel composition. Therefore, kernels are susceptible to scorching during continuous exposure at high temperature. Considering the economy of the processing, which is highly influenced by the quality of kernels obtained at the peeling stage, the kernels should be exposed to lower temperature for the purpose of loosening testa.

Kernels, after extraction from the nut will have moisture and the skin will be difficult to peel immediately. In order to remove the skin, kernels must be exposed in the controlled environment and cooled for a certain period. This alternative heating and cooling will shrink the kernel and loosen the skin enabling manual peeling using small knives. Increasing wholes to broken ratio and decreasing the difficult to peel kernels should be the ultimate aim in the peeling process. In addition, the technical parameters in kernel drying must be optimized to ease the peeling operation and reduce the scorching of kernels for better economic efficiency.

The effect of various air temperatures and kernel cooling periods on the kernel quality at peeling is depicted in **Figs. 3** and **4**. It is clear that the whole kernel recovery is stable at temperatures of 70 ºC and 80 ºC (range 73.11 to 77.56 percent)

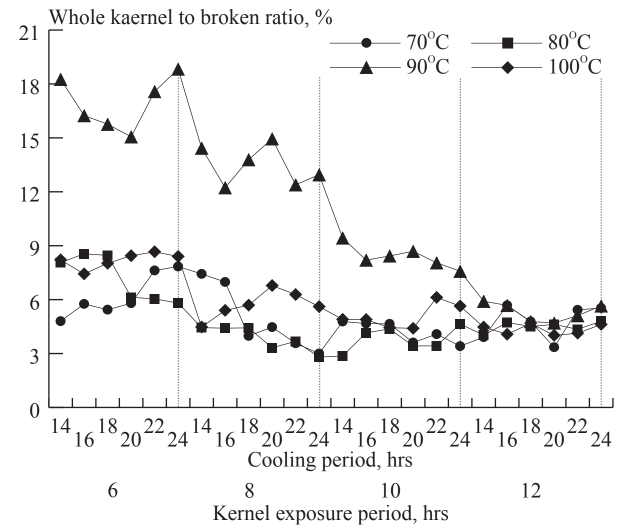

Fig. 3 Effect of drying parameters on wholes to broken ratio in peeling process

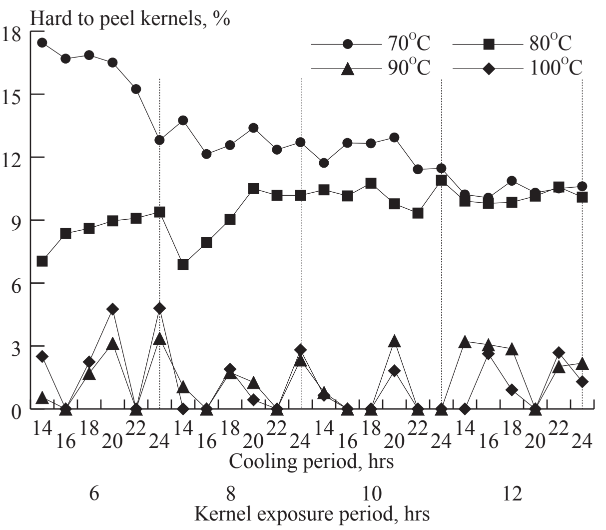

Fig. 4 Effect of drying parameters on difficult to peel kernels in peeling process

irrespective of the cooling period. The value increased above 80 percent when it was subjected to 90 ºC and 100 ºC (range 82.50 to 92.90), but the kernels turned light to deep brown due to scorching. These scorched kernels were edible, but it is not preferred when the economic efficiency of the processing system is concerned. Thus, exposing the kernels to high temperatures above 80 ºC must be avoided for better economic results. Longer heating periods for kernels of 10 and 12 hrs have caused them to become highly brittle and cause more breakage during manual peeling. Higher values of WBR at 6 and 8 hrs indicated that the kernels must be exposed in hot air for shorter time in order to ease the operation of peeling. Although higher values of WBR were obtained at 90 ºC and 100 ºC this is not feasible due to kernels scorching.

The quality index value for the kernel output in relation to optimization of kernel drying parameters is given in **Table 5**. The polynomial equations framed with optimum values at different cooling periods are presented in **Table 6**. The optimum values for kernel drying parameters viz., air temperature, length of drying inside borma and kernel cooling period in ambient environment are shown in **Figs. 5a**, **5b**, and **5c**. Following the optimization technique, it is observed that kernels exposed to hot air maintained at 70 ºC for 6 hours and cooling subsequently for a period of 24 hours can yield better results at the peeling stage. Practically, industries require at least 24 hours time to pass on the kernels from one stage to another. Since the quality index at these kernel-drying parameters is optimum, this blends with the industry practice.

Conclusions

1. Wide variation in the size of nuts and absence of grading based on nut size led to 16 percent kernel damage in shelling by longitudinal cracks in the extracted kernels. The dimensions of the raw nut showed that Nigerian nuts are highly irregular shape, demanding correct ma-

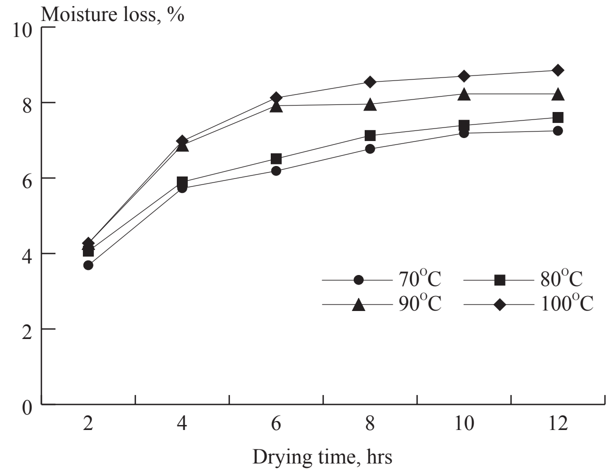

Fig. 2 Rate of drying of cashew kernels at various temperature

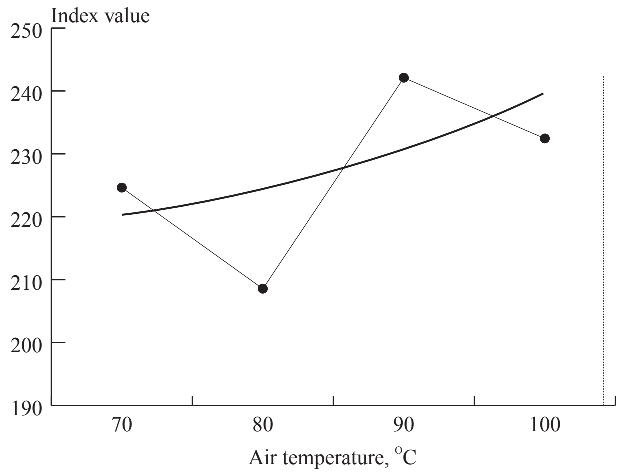

Fig. 5a Optimizing of kernel drying parameters for cashew nuts of Nigeria - air temperature

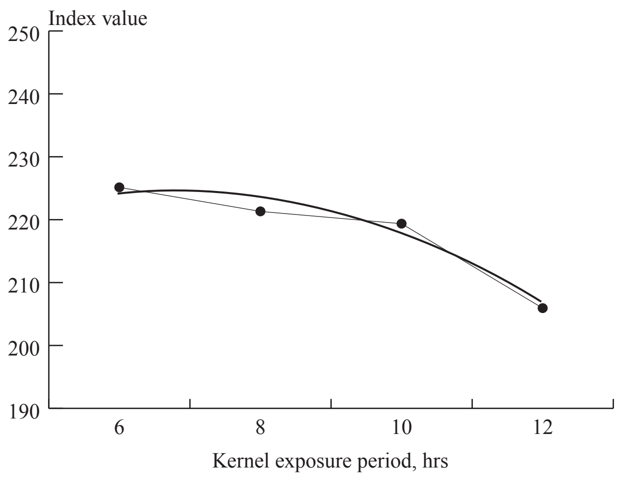

Fig. 5b Optimizing of kernel drying parameters for cashew nuts of Nigeria - exposure period

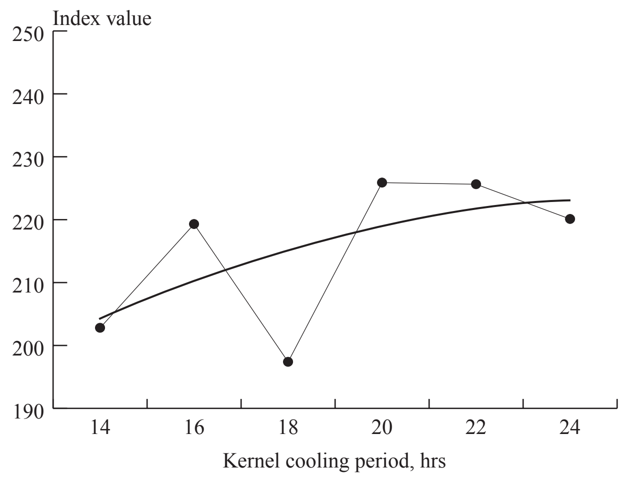

Fig. 5c Optimizing of kernel drying parameters for cashew nuts of Nigeria - cooling period

nipulation according to size during the de-shelling operation to avoid damage to the kernel.

2. Ineffective peeling method is the major cause for high proportion of broken kernels at the peeling stage. Removing skin at the lateral sides could avoid scratching of kernels by knife and ease the peeling process, as the skin adherence is more on the sides of the kernels.

3. The moisture content of raw nut determined by toluene distillation method is in the range of 4.12 to 7.31 percent d.b. showing the nuts were well dried before processing. A major portion of difficult to peel kernels is due to immature nuts in the processing line, which is evident from the proportion of shriveled kernels at packing, i.e. 16.4 percent.

4. A significant rate of moisture removal took place during the initial phase of kernel drying irrespective of hot air temperature mainly due to the loss of free moisture from the kernel. During bound moisture removal in subsequent phase of drying, care should be taken to avoid change in chemical composition and loss of volatile components of kernel.

5. Exposing the kernels to higher temperatures of 90 ºC and 100 º C, made the skin removal easy and enhanced operational capacity. However, this caused a high proportion of the kernels to be scorched. Thus, the unpeeled kernel should be exposed to lower temperature to obtain a higher quantity of white whole kernels.

6. The whole kernel recovery was 77.56 percent, when the kernels were dried in a cross flow drier subjected to 70 ºC for 6 hours. This recovery was 37 percent higher than the presently used conventional type borma drier.

7. The adherence of testa was highly related to the amount of moisture present in the testa and the kernel. The amount of manpower spent on careful peeling of difficult to peel kernels reduced operational capacity. Longer kernel drying tended to remove more moisture and makes the kernel brittle irrespective of cooling period. This results in more broken and scorched kernels while peeling.

8. To improve the economic results by lowering the quantity of difficult to peel kernels in the peeling stage, the raw nuts must be subjected to steam at 100 PSI for 33 minutes and cooled in an ambient environment for a minimum of 18 hrs. The kernels obtained from shelling must be exposed to hot air temperature of 70 ºC for 6 hrs continuously in a cabinet type drier followed by 24 hrs cooling to ease peeling operation and increase peeling output.

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Notations

PSI: Pounds per square inch
MT: Metric tones
LC: Least count
Db: dry basis
Mm: millimetre
CNSL: Cashew Nut Shell Liquid
Kg: Kilogram
WBR: Whole to Broken kernel Ratio
DPK: Difficult to Peel Kernels
ºC: degree centigrade
cm^3: Cubic centimetre

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Processing Factors Affecting the Yield and Physicochemical Properties of Starches from Cassava Chips and Flour

by

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Abstract

Three processing factors, namely, raw materials type (RMT) (i.e. chips and flour) and raw material drying mode (RDM) (i.e. sun and oven-drying at 55 ºC) were related to the yield and some physicochemical properties of starch in a 23 factorial experiment. The quality characteristics investigated were: moisture content, pH, crude fibre content, peak viscosity and pasting temperature. Starch yields from oven-dried chips and flour were significantly higher (at 5 %) than from sun-dried materials. The optimal yield of 55.90 g (per 70 g of dried product or 79.9 %) was obtained from oven-dried starch extracted from oven-dried flour. The peak viscosity (PV) of starches extracted from flours were significantly higher than those from chips with average values of 565.22 and 550.08 RVA units respectively, while the pasting temperatures (PT' s) of flour-extracted starch were lower than starches from chips with mean gelatinization temperatures of 76.44 ºC and 76.50 ºC respectively.

Introduction

Cassava processing in Nigeria is still characterized by features, which exercise a limiting effect on product diversification and widespread utilization. Since cassava is cultivated principally in smallholder farms across the country, the quantity of harvested roots that is commercially available is not large, and when there are surpluses, the problem of commodity agglomeration and linking with industrial processors become daunting. The transformation of cassava into high quality starch from stable cassava products like chips and flour will have a phenomenal facilitating effect within the general cassava processing sub sector and for starch extraction activities in particular. As noted by Thro et al. (1994), the increasing importance of cassava as an industrial crop makes the logistics of supplying fresh cassava to processing locations more critical. The capacity to store cassava roots in the form of chips and flour for more than a few days would provide processors with the operational flexibility of inventorying a reserve of raw material, thereby operating with much greater efficiency (Ajibola, 1996). The need to establish these possibilities has therefore provided the impetus for carrying out this research work with a view to investigating the processing factors influencing the extraction of starch from cassava chips and flour.

Materials and Methods

Fresh cassava roots (Manihot esculenta Crantz) of a local variety ("oko iyawo") were obtained from a private farm inside the Obafemi Awolowo University (OAU), Ile-Ife, Nigeria.

Preparation of Dried Raw Materials (Experiment 1)

A Hallde dicing machine (A.B. Hallde, Maskiner, Sweden) was used to produce peeled cassava chips of approximately 10 x 10 x 10 mm in size. These were collected in drying trays and subsequently sun and oven-dried. Sun-drying was continued until no further loss in weight of the diced roots was noticed. Oven drying was carried out at a temperature of 55 ºC using standard procedures in a Gallenkamp moisture extraction oven. Drying was deemed to be complete when there was no further loss in weight over a 24 hr period. The final moisture content was then determined. Similarly, dried cassava flour was produced by weighing and grating fresh roots in an electric motor-powered mechanical cassava grater. The ensuing mash was put into a permeable high-density polypropylene sack, and immediately dewatered in a screw press. The dewatered cakes were weighed into trays to be dried in the sun at ambient temperature, and in the oven at 55 ºC. Other drying procedures and methods apply as identified for chips above.

Extraction of starch from roots and dried products (Experiment 2)

Each of the sets of chips and flour produced by the two drying modes described above (viz., sun-drying and oven-drying at 55 ºC) was ground in a vertical shaft hammer mill with a screen size of 300 µm sieve bowl, and the starch milk allowed to settle for 8 hours. This was followed by the decantation of the supernatant and dewatering of the starch sediment in a screw press. The dewatered starch cakes from each of the samples (i.e. from oven and sun-dried chips and flour) were spread on drying trays, and put separately in the sun, and oven at 55 ºC in 2 x 2 drying experiments. Each of these samples was replicated twice. Relatively low drying temperatures were used because it is known that gelatinization of cassava starch occurs at 70 ºC and above.

A 2^3 factorial experiment was performed to investigate the effects of dried raw materials type (RMT), raw material drying mode (RDM) and starch drying mode (SDM) on the yield and physicochemical properties of the starch produced. Each factor was investigated at two levels, yielding eight treatment combinations (see **Table 1** for the results of the factorial experiments).

The moisture content of samples was determined using standard procedures in a Model 28, Thelco Lab Oven (Precision Scientific, GCA Corp., USA). pH was determined by dissolving 10 g of each sample in 10ml of distilled water, and allowed to stand for 30 min. The pH of the filtrate was determined with a Cole Parmer digital meter (Cole Parmer Instrument Co., Chicago, Illinois). The pasting temperature and peak viscosity of the starch samples were determined using a rapid visco analyzer (RVA). The RVA (Newport Scientific Rapid Visco Analyzer) with Microsoft Thermocline for Windows Software (Microsoft Inc., USA), HP 690C Printer (Hewlett Packard Inc., USA) and Computer Monitor (Dell Corp. USA) were used to assess the quality of the starch samples. The precise ramped heating and cooling abilities of the RVA, along with steady state temperature control, allowed careful control of the cooking environment, while changes in viscosity were continually recorded. The crude fibre content of the samples was determined using the AOAC Method of Analysis (AOAC, 1978). The data in **Table 1** were analysed using the Yates algorithm; the two and three factor interactions were used as estimates of the standard errors where appropriate (Box et al., 1978). A computer program (SAS, 1987) was used to derive the F-values and factors significant at the 5 % level.

Results and Discussion

Analysis of the results of the 2^3 factorial experiment (**Table 1**) indicated that starch yields were significantly affected by the raw material drying mode RDM (**Table 2**). Oven-dried materials (chips and flour) gave yields, which were significantly higher (at 5 %) compared with those from sun dried materials. A review and comparison of the unit operations for the production of chips and flour indicated that the more comprehensive size reduction and dewatering operations for flour production would normally lead to the loss of some starch molecules in suspension during the period. According to Ajibola (1987) however, the quantity of starch molecules lost during the mash dewatering process was not significant. It can therefore be hypothesized that the lower starch yields from chips may be due to internal activities occurring during the other processes of starch extraction from the dried

Experiment number	Factors			Crude starch yield/70 g DM (mean)	Moisture content (mean)	pH	Crude fibre	Peak viscosity (mean)	Pasting temp. (mean)
	RMT	RDM	SDM						
1 (B3)	Chips	Sun	Sun	34.15 (48.8 %)	10.93	5.50	-	520.75	76.58
2 (B1)	Flour	Sun	Sun	43.80 (62.6 %)	12.10	4.99	-	556.84	76.40
3 (B4)	Chips	50 ºC	Sun	48.95 (69.9 %)	10.93	4.70	1.93	556.25	76.58
4 (B5)	Flour	50 ºC	Sun	55.45 (79.2 %)	10.80	5.03	-	566.46	76.40
5 (B5)	Chips	Sun	55 ºC	39.20 (56.0 %)	10.56	5.12	0.29	557.42	76.50
6 (B7)	Flour	Sun	55 ºC	48.70 (69.6 %)	10.52	5.11	-	522.33	76.35
7 (B6)	Flour	55 ºC	55 ºC	45.35 (64.8 %)	10.20	4.80	-	566.92	76.45
8 (B8)	Flour	55 ºC	55 ºC	55.90 (79.9 %)	10.72	5.14	-	615.25	76.50

Table 1 Results of 2 factorial experiment to determine the effects of RMT, RDM and SDM on the yield and quality of extracted starch (Experiment 2)

chips and flour samples. Giraud et al. (1994) observed significant variations in the pH of sun and oven-dried cassava flour, with the latter being lower. They suggested that the pH increase during sun drying (of starch samples) might be due to the consumption of lactic acid in a chemical reaction. Lactic acid can be transformed during sun drying to either lactate or the lactic form may disappear. The activities of bacteria converting (fermenting) cassava starch to lactic acid was probably more pronounced for starch extracted from sun-dried raw materials than for oven-dried ones, leading to the greater crude starch yields from the latter compared to the former. Starch drying mode (SDM) did not have any significant effect on yield (**Table 2**). The mean starch yields from flour and chips are 50.96 g and 41.91 g (per 70 g of dried product) respectively. This difference is significant at 5 % using the Duncan's Multiple Range Test. Even though a particle size analysis of the disintegrated dried flour and chips was not undertaken, it was observed that the coarse aggregates in the latter were much higher than the former. This was evidenced in the large quantities of coarse overflows (for chips) during screening of the solubilized "flours" to filter out the starch milk. Henderson and Perry (1976) indicated that the size and shape of the individual grains in any mass of material would depend upon the history and method of reduction. Since the methods of size reduction and drying were similar for both dried raw material types, the variation in the consistency for the ensuing hammer milled flour can be attributed to differences in their physical characteristics (i.e. size of the chips compared with unmilled flour). It was obvious during the experiment that the fineness modulus (FM) of the milled chips was much higher than the corresponding flour samples. Therefore, the greater starch yields from dried (grated, dewatered cassava mash) flour was to be expected in view of the greater degree of the size reduction and the resultant relatively better access of the solvent (water) to wash out the starch granules from the cells of the flour compared with chips. Essentially, it can be deduced that given similar communition conditions (equal milling time in screen, of equivalent mesh openings) starch yields from flour will be greater than from chips, except probably, if the two samples are ground in a manner to ensure equality of the fineness moduli of the ensuing milled samples.

Effects of Processing Conditions on Starch Quality

Most of the starch samples assayed had no crude fibre in them. The Duncan's Multiple Range Test indicated that RDM had no significant effect on the moisture content (MC) of the starch samples produced. The mean MC for oven and sun-dried samples was 9.413 and 10.033 % (w.b.) respectively. A study of the effects table developed from the Yates Algorithm table indicated that RDM significantly affected pH; but there was also significant interaction of RMT and RDM (**Table 3**). This interaction may be explained as the combined effects of differential drying rates in chipped and grated cassava roots (RMT), and the more controlled and uniform oven-drying conditions compared with the more variable sun-drying profile (RDM). Under similar drying conditions, cassava flour would be expected to dry faster than chips in view of the greater surface area available for moisture movement and evaporation compared to chips, whose lower degree of size reduction hinders speedy moisture migration to its surface and therefore lower water evaporation (and drying rates). The foregoing is relevant to the respective pH levels recorded for chips and flour when the importance of

Effect	Estimates + standard error	F value	Pr>F
Average	46.44 + 0.75		
Main effects			
Raw material type (T)	9.05 + 1.50	71.11	0.0001
Raw material drying mode (D)	9.95 + 1.50	85.95	0.0001
Starch drying mode (S)	1.70 + 1.50		
Two-factor interactions			
TD	-0.53 + 1.50		
ST	0.98 + 1.50		
SD	-3.28 + 1.50		
Three-factor interactions			
TDS	1.05 + 1.50		

Table 2 Effects of factors on crude starch yields (CSYs)

Effect	Estimates + standard error	F value	Pr>F
Average	5.05 + 0.06		
Main effects			
Raw material type (T)	0.04 + 0.13		
Raw material drying mode (D)	0.26 + 0.13	4.41	0.1706
Starch drying mode (S)	-0.01 + 0.13		
Interactions			
TD	0.29 + 0.13	5.46	0.1404
ST	0.13 + 0.13		
SD	0.12 + 0.13		
TDS	0.13 + 0.13		

Table 3 Effects of factors on pH

water (moisture) for the facilitation of the fermentation process is considered. Bokanga (1995) indicated that nearly all fermentations rely on the fortuitous presence of microbes on the roots and/or in the water, and on the prevailing favourable conditions. One of the conditions for promoting microbial (or bacterial) activity is the presence of moisture. The degree of fermentation (with pH as index) is related to the relative duration of moisture availability. This relationship between pH and moisture availability partly explains the effect of the RMT and RDM interactions on pH. The difference in the mean pasting temperatures of sun and oven-dried materials (76.46 ºC and 76.45 ºC respectively) is not significant. There were no discernible correlations between starch pH and the PT's for starch extracted from either oven-dried or sun-dried materials.

Analysis of the results of experiment 2 indicated that each of RDM, RMT and starch drying mode (SDM) had significant effects on peak viscosity. **Table 4** shows that the estimate of the three-factor interaction was about twice that of the highest two-factor interaction; (14.39 for RMT * RDM Versus 27.33 for RDM * RMT * SDM). It was therefore plausible, that a three-factor interaction was indicated as having significant effects on the PV. The experiment showed that starches extracted from oven-dried raw materials exhibited higher peak viscosities compared with those extracted from sun-dried feed stocks. The observed lower PV of starches from sun-dried raw materials may be due to the progressive carry over of the PV characteristics of the oven-dried materials from experiment 1, which were themselves characterized by higher PV's compared with the PV' s of sun-dried chips and flour (i.e. 450.56 Vs 448.50 RVA units). It was also found that the PV for flour-extracted starch was significantly higher than those extracted from chips. This may also be attributed to a projection of the initial tendency of the dried raw materials themselves. From experiment 1, we noted that the PV of flour samples was significantly higher than that for chips (i.e. 502.12 Vs 396.94 RVA units). Finally, it was observed that oven-dried starch samples possessed peak viscosities much higher than sun-dried starches. This finding agreed with that of Dufour et al. (1994) who observed that fermentation and sun drying modified the rheological properties of the starch and produced a more marked retro gradation and lower maximum viscosity. Retro gradation is an increased rigidity in the starch gel that occurs as starch granules re-associate during cooling, sometimes leading to syneresis or the release of water (Safo-Kantanka and Acquistucci, 1994). It appears that the consistent correlation between crude starch yields and peak viscosities in the three interacting factors is responsible for their significant interactive effect on PV. From the data generated in this work, it was observed that crude starch yield is the most prominent common characteristic affecting PV values. This agrees with the work of Moorthy et al. (1994) who suggested that the lower starch content of flour samples could account, in part, for their lower peak viscosities compared with the PV's of corresponding starches extracted from the same cassava root. This proposition finds concurrence with the findings in this work, and confirms the validity of the three-factor interaction, viz.: oven-dried starch (SDM) from oven-dried flour (RDM and RMT) gave PV values greater than any other alternative factor combinations.

RMT was implicated in the analysis as having a significant effect on pasting temperature, PT, with the gelatinization temperature of starch extracted from chips being higher than those from flour. Further to this observation was the significant effect of a three-factor interaction

Effect	Estimates + standard error	F value	Pr>F
Average	557.78 + 4.31		
Main effects			
Raw material type (T)	14.89 + 8.61	11.30	0.0211
Raw material drying mode (D)	36.89 + 8.61	68.02	0.0001
Starch drying mode (S)	-15.41 + 8.61	12.09	0.0103
Interactions			
TD	14.39 + 8.61	9.86	0.0164
ST	-8.27 + 8.61		
SD	14.33 + 8.61		
TDS	27.33 + 8.61	37.50	0.0005

Table 4 Effects of factors on peak viscosity (P.V)

Effect	Estimates + standard error	F value	Pr>F
Average	76.47 + 0.02		
Main effects			
Raw material type (T)	-0.12 + 0.04		
Raw material drying mode (D)	0.03 + 0.04		
Starch drying mode (S)	-0.04 + 0.04		
Interactions			
TD	0.05 + 0.04		
ST	0.07 + 0.04		
SD	0.03 + 0.04		
TDS	0.05 + 0.04	5.89	0.0456

Table 5 Effects of factors on pasting temperature

(RMT * RDM * SDM) on PT. F = 5.89 (Pr>F) = 0.0456 (**Table 5**). This three-factor interaction can be viewed as combining factor levels in such a manner as to produce variable starches (from chips and flour), which have different lipids and sugar contents. Such components within the samples, by variably restricting access of water into the starch granules, can delay gelatinization, thereby creating differences in the PT values. According to Osman (1967), surfactants and lipids, by forming complexes, can raise gelatinization temperatures. Lipids, in common with many surfactants, are also identified by Krog (1973) as significantly affecting starch by complexing strongly with amylose and amylopectin side chains. The foregoing can be ascertained by subjecting the starch samples to defatting and ethanol extraction before carrying out the viscoamylographic analysis.

Conclusions

The following deductions were made from the results and analysis carried out in this work.

1. Raw material type (RMT) had a significant effect on starch peak viscosity. The peak viscosities of starch samples from chips were significantly lower than those extracted from flour.

2. Raw material drying mode (RDM) was positively correlated to starch yield and peak viscosities, as oven-dried raw materials had significantly higher crude starch yields and higher peak viscosities.

3. Neither raw material type (RMT) nor raw material drying mode (RDM) had any significant effect on pasting temperatures (PT's) of the dried raw materials. RDM and starch drying mode (SDM), similarly had no significant effects on starch gelatinization temperatures, but RMT significantly affected starch PT.

4. The quality characteristics of oven-dried starch samples extracted from oven dried cassava flour (Sample B8) was found to be optimal or close to the highest standards required by a cross section of relevant industries (i.e. the paper manufacturing and certain categories of the food industries in the USA).

5. The result of this research has demonstrated the possibility of producing high quality starch from dried cassava products rather than from bulky fresh roots, which make cassava-processing operations inflexible and often logistically precarious. The benefits of this possibility for Nigerian farmers, the nation's cassava processing industries and the economy are numerous.

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Influence of Seeding Depth and Compaction on Germination

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Abstract

Field studies were conducted to observe the effect of depth of seeding and soil compaction on germination for crops, namely, black gram (*Vigna mungo* (L.) Hepper), maize (*Zea mays* L.), cotton (*Gossypium hirsutum* L.) and gingelly (*Sesamum indicum* L.). Different soil compaction levels viz., 1.1, 1.2, 1.3, 1.4 and 1.5 g cm^{-3} were applied by means of a roller press wheel. A simple low cost pressure-sensing device was developed to measure the soil compaction in the field at different seeding depths. The study revealed that soil surface compaction levels of 1.3 and 1.2 g cm^{-3} and seedling depths of 2.5 and 5.0 cm, yielded maximum seed germination for black gram and maize, while for cotton and gingelly seed germination was maximum at 2.5 and 2.0 cm seeding depths at a surface compaction level of 1.1 g cm^{-3}.

Introduction

A viable seed's germination sown in a well-pulverized soil may be affected by its contact with the soil for moisture. This problem can be eliminated to a certain extent by compacting the seeds to the desired level. Studies showed that the emergence of seedling improved progressively by increasing planting depths from 0 to 2.5 cm and soil compaction from 0 to 0.84 kg cm^{-2} (Triplett and Tesar, 1960). The surface compaction below 0.04 kg cm^{-2} decreased cotton seed emergence (Elmer and Wanjura, 1970). The position at which the seed is compacted also significantly affects the germination. When pressure above 0.05 kg cm^{-2} was applied over the seed level, 60 and 65 % seedling emergence was observed for wheat and maize respectively. But seedling emergence of 95 and 90 % were obtained for wheat and maize respectively at the same moisture levels and pressure over the soil cover (Pathak et al., 1976).

The measurement of soil compaction in terms of bulk density is more reliable than the penetration resistance, as it is associated with the changes in pore space and void ratio of the soil (Koolen and Kuipers, 1983). It is cumbersome to measure the soil compaction in the field precisely at different depths. A foil type strain gauge pressure transducer was used to measure the compacting load over the seed in a triaxial pressure cell (Johnson and Henry, 1967). A miniature strain gauge pressure transducer was also developed to measure the soil pressure instantaneously by a passing coulter (Baker and Mai, 1982). The methods developed to measure the compaction of soil are very costly and trained personnel are needed to make observations. In this study, a simple low cost pressure-sensing device was developed to measure the soil compaction at different depths. The effect of soil compaction on seed germination was also investigated for crops, namely black gram, maize, cotton and gingelly in the field.

Materials and Methods

The experiment was conducted in sandy clay loam soil (USDA classification) that consisted of 33.8 % clay, 8.21 % silt, 29.6 % fine sand and 23.08 % coarse sand. The apparent specific gravity of the soil was 1.2 to 1.35 and infiltration rate was 1.5 to 2 cm h^{-1}.

Development and Calibration of a Pressure Sensor

To measure the compaction of soil, a simple pressure sensor that consisted of a rubber tube sealed at both ends and fixed with two mouths was developed (**Fig. 1**). The sensor was filled with water and one mouth was closed with a pin. The other mouth was left open and connected to a graduated manometer of 525 mm length. It was calibrated for soil bulk densities of 1.0-1.5 g cm^{-3} at an interval of 0.1 g cm^{-3} using a simple test rig. The test rig consisted of a 45 x 30 x 15 cm box with the prepared soil sample. A soil sample of 18 kg was collected from the field in which the study was to be undertaken. The soil sample was kept in an oven for 48 h for drying at 105 ºC. It was then allowed to pass through a 2 mm Indian Standard sieve. The soil was mixed with 8 litre of water to obtain the soil moisture content of 46 % (w.b.). This moisture content was selected so as to have good seed germination (Reddy and Reddy, 1995). The wet soil was then transferred to the box in 2.5 cm layers and compacted with a Standard Proctor compacting device (Punmia, 1994). The manometric displacement at the particular bulk density was observed. The experiments were repeated until concurrent values were obtained. The relationship between the bulk density and manometric displacement was obtained as, Y = 26x - 8.04, where, Y = manometric level, cm and x = bulk density, g cm^{-3}.

Development of Field Compacting Device

To compact the soil in the field after sowing the seed, a roller press wheel that consisted of a mild steel roller of 10 cm diameter and 30 cm long, weighing 27 kg, was fabricated (**Fig. 2**). It developed a pressure of 0.03 kg cm^{-2} so as to make the soil bulk density of 1.1 g cm^{-3}. Additional weights made of 32 mm diameter mild steel rods and 30 cm length weighing 2.5 kg were added successively to increase the bulk density of soil to 1.2, 1.3, 1.4 and 1.5 g cm^{-3} respectively. A rectangular box was also provided over the roller to add additional weights to increase the pressure uniformly (Gabrilides and Akritidis, 1970).

Accomplishment of Field Compaction Level

Initially the field was irrigated until it reached field capacity. The moisture was allowed to deplete to 46 % (w.b.). The pressure sensor was placed at the desired depth of the seed with a spacing of 2 m. Black gram and maize were dibbled at 2.5 and 5 cm depths, while cotton and gingelly were placed at 2 and 3 cm depths by means of a specially made dibbling device which maintained the depth precisely. The roller wheel with the known weight was rolled at normal walking speed of 2 km h^{-1} until soil reached the manometric displacement corresponding to the required bulk density.

Lay out of Experiment

A field of 0.16 ha was selected for the study. It was divided into four equal plots. The experiment was laid out using the Factorial Randomised Block Design with 6 x 2 x 4 x 4 treatments as bulk density, depth, type of seed and replications respectively. The seed rates adopted were 15, 15, 10, and 5 kg ha^{-1} respectively for black gram, maize, cotton and gingelly (Anon, 1999). The viability of these seeds were respectively 92 %, 99 %, 80 % and 79 %. Life irrigation was provided two days after planting. The seeds germinated per hill were observed and recorded up to eighth days after dibbling. Beyond that no germination was observed.

Results and Discussion

The pressure sensor developed

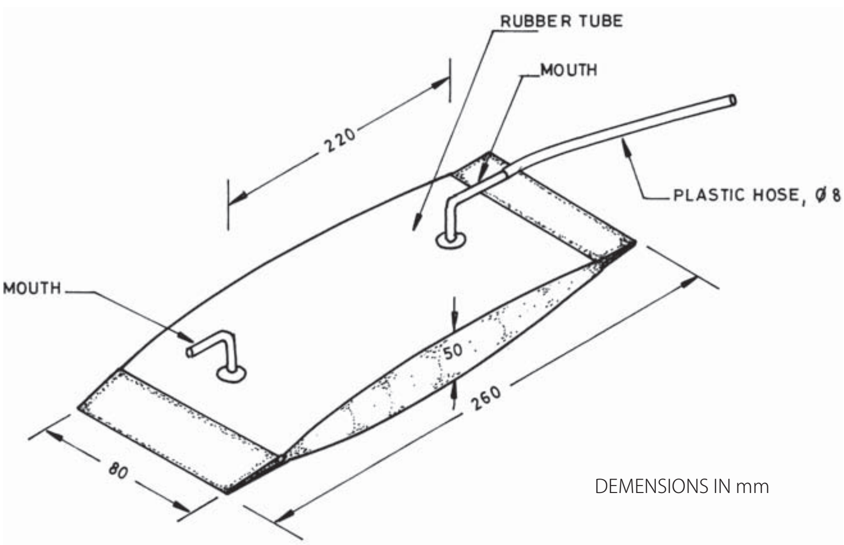

Fig. 1 Pressure sensor

to observe the bulk density worked satisfactorily in field conditions. The required compaction was accomplished with the roller wheel.

Effect of Compaction on Seed Germination

The effect of compaction on seed germination for black gram, maize, cotton and gingelly were recorded at two seeding depths. The results were analysed using the statistical package "AGRES". Standard Dunken's Multiple Range Test results were obtained with the mean comparison to know the main and interaction effects. Analysis of variance for seed germination with respect to black gram, maize, cotton and gingelly are presented in **Table 1**, **2**, **3** and **4** respectively. It was inferred that the main effect was highly significant for black gram while the interaction effect was significant. It was also observed that all the main and interaction effects were highly significant for maize, cotton and gingelly respectively.

The interaction between different compaction levels and depth of dibbling black gram is depicted in **Table 5**. From the table, it was observed that the germination was highly significant at a bulk density of 1.3 g cm^{-3} than any other treatments at 2.5 cm depth of dibbling. The seed germination at 1.1, 1.2, and 1.4 g cm^{-3} compaction levels are on par. The compaction level at 1.5 g cm^{-3} resulted in poor seed germination and could be compared with the control. The seed germination at 5.0 cm depth of dibbling revealed that the compaction level of 1.3 g cm^{-3} was significantly different from 1.1 g cm^{-3}. But, the treatment of 1.3 g cm^{-3} bulk density was highly significant when compared with other treatments. The treatments of 1.2, 1.4 and 1.5 g cm^{-3} and control were on par. The interaction of factor means for depth of dibbling indicated that seeding at 2.5 cm depth significantly improved the seed germination as compared to 5.0 cm, irrespective of compaction level. The results concluded that the seed germination at a compaction level of 1.3 g cm^{-3} and seeding depth of 2.5 cm yielded the best germination. Dibbling the seed at 5 cm depth without compaction and 1.5 g cm^{-3} compaction level yielded the lowest germination.

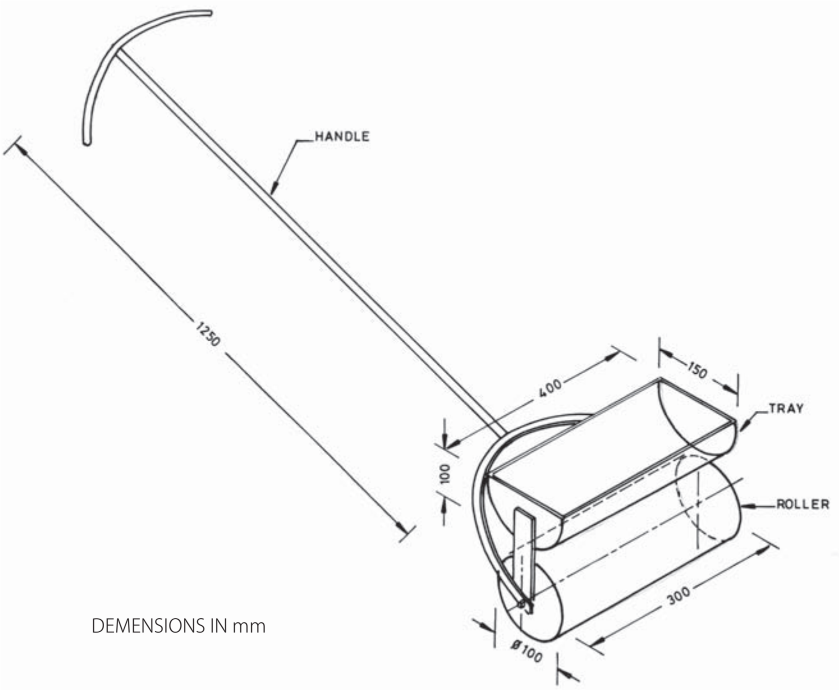

Fig. 2 Roller press wheel

The interaction between the treatment combinations of different bulk densities and depth of dibbling maize is shown in **Table 5**. It was inferred germination was highly significant at 2 g cm^{-3} compaction level as compared to any other treatments at 2.5 cm depth of sowing. The seed germination at 1.1 and 1.4 g cm^{-3} compaction levels and control were on par. The compaction level at 1.3 and 1.5 g cm^{-3} resulted in poor germination and were on par. The seed germination at 5.0 cm depth of dibbling revealed that the compaction level at 1.2 g cm^{-3} bulk density was highly significant as compared to any other treatments. The treatments 1.1 and 1.3 g cm^{-3} and control were on par. Seedling emergence at 1.5 g cm^{-3} compaction level was the lowest. The interaction of factor means for different depth of dibbling indicated that dibbling at 5.0 cm was highly significant as compared to 2.5 cm depth, irrespective of compaction level. From the results, it was concluded that the seed germination at a compaction level of 1.2 g cm^{-3} and dibbling depth of 5.0 cm yielded the best germination. Dibbling the seed at 5 cm depth and compacting at 1.5 g cm^{-3} yielded poor germination.

The interaction between the treatment combination of compaction levels and depth of dibbling of cotton is summarised in **Table 5**. The factor interaction effects revealed that germination was highly significant at 1.1 g cm^{-3} bulk density as compared to any other treatments at 2.5 cm depth of dibbling (Johnson and Henry, 1964). The seed germination at 1.2 g cm^{-3} compaction level was on par with the control. The compaction levels at 1.4 and 1.5 g cm^{-3} resulted in poor seed germination. The seed germination of the control was highly significant at 5.0 cm depth of dibbling as compared to any other treatment. The seed germination at 1.1 and 1.2 g cm^{-3} compaction levels were on par. The compaction level at 1.3, 1.4 and 1.5 g

cm^{-3} resulted in poor seed germination. The interaction effects inferred that dibbling at 2.5 cm depth was highly significant as compared to dibbling at 5.0 cm depth, irrespective of compaction level. The results concluded that the seed germination at 1.1 g cm^{-3} compaction level and 2.5 cm depth of dibbling yielded the best germination. Sowing the seed at 5.0 cm depth and compacting at 1.3, 1.4 and 1.5 g cm^{-3} level yielded lower germination.

The interaction effect of bulk densities and depth of dibbling gingelly is presented in **Table 5**. The seed germination at 2.0 cm depth of sowing revealed that the compaction level of 1.1 g cm^{-3} was significantly different than 1.2 g cm^{-3} and control. The seed germination at 1.3, 1.4 and 1.5 g cm^{-3} compaction levels resulted poor seed germination and were on par. It was also observed that the germination was highly significant at 1.1 g cm^{-3} compaction level as compared to any other treatments at 3.0 cm depth of dibbling. The seed germination at control was better than 1.3 and 1.4 g cm^{-3} compaction level. At 1.5 g cm^{-3} compaction, the seed germination was the lowest. The interaction of factor means for different depths of dibbling indicated that dibbling at 2.0 cm depth was highly significant as compared to 3.0 cm, irrespective of compaction level. The results concluded that the seed germination at 1.1 g cm^{-3} compaction level and 2.0 cm depth of dibbling yielded the best performance followed by the same compaction level with seeding depth of 3.0 cm. Sowing the seed at 3.0 cm depth and compacting at 1.5 g cm^{-3} resulted in lower germination.

Conclusions

A low cost pressure sensor was developed and calibrated to measure the soil compaction level. The soil surface compaction level at 1.3 g cm^{-3} and seeding depth of 2.5 cm yielded maximum black gram germination, while maize at 1.2 g cm^{-3} and 5.0 cm yielded maximum germination. The soil surface compaction level at 1.1 g cm^{-3} and seeding depth of 2.5 cm yielded maximum cotton germination whereas, the compaction level at 1.1 g cm^{-3} and seeding depth of 2.0 cm yielded maximum gingelly germination. In summary a seeding depth of 2.5

Table 1 Analysis of variance for black gram

Source of variation	Degrees of freedom	Sum of squares	Mean sum of square	F-value
Total	47	1,021.47	21.73	6.88
Replication	3	1.06	0.35	0.11
Treatment	11	916.22	83.29	26.38**
Error	33	104.18	3.15	1.00
Bulk density	5	661.35	132.27	41.89**
Depth	1	212.52	212.52	67.31**
Bulk density x depth	5	42.35	8.47	2.68*
Error	33	104.18	3.15	1.00

C.V. = 8.87 %, **Significant at 1 % level, *significant at 5 % level

	SED	CD (P = 0.05)	CD (P = 0.01)
Bulk density	0.88	1.80	2.42
Depth	0.51	1.04	1.40
Bulk density x depth	1.25	2.55	3.43

Table 2 Analysis of variance for maize

Source of variation	Degrees of freedom	Sum of squares	Mean sum of square	F-value
Total	47	286.31	6.09	10.57
Replication	3	2.73	0.91	1.58
Treatment	11	264.56	24.05	41.73**
Error	33	19.02	0.58	1.00
Bulk density	5	209.19	41.84	72.59**
Depth	1	6.02	6.02	10.45**
Bulk density x depth	5	49.35	9.87	17.13**
Error	33	19.02	0.58	1.00

C.V. = 10.05 %, **Significant at 1 % level

	SED	CD (P = 0.05)	CD (P = 0.01)
Bulk density	0.38	0.77	1.04
Depth	0.22	0.45	0.59
Bulk density x depth	0.54	1.09	1.47

Table 3 Analysis of variance for cotton

Source of variation	Degrees of freedom	Sum of squares	Mean sum of square	F-value
Total	47	355.67	7.57	9.36
Replication	3	1.33	0.44	0.55
Treatment	11	327.67	29.79	36.86**
Error	33	26.67	0.81	1.00
Bulk density	5	199.17	39.83	49.29**
Depth	1	96.33	96.33	119.21**
Bulk density x depth	5	32.17	6.43	7.96**
Error	33	26.67	0.81	1.00

C.V. = 11.61 %, **Significant at 1 % level

	SED	CD (P = 0.05)	CD (P = 0.01)
Bulk density	0.45	0.91	1.23
Depth	0.26	0.53	0.71
Bulk density x depth	0.64	1.29	1.74

Table 4 Analysis of variance for gingelly

Source of variation	Degrees of freedom	Sum of squares	Mean sum of square	F-value
Total	47	1,506.00	32.04	25.69
Replication	3	0.83	0.28	0.22
Treatment	11	1,464.00	133.09	106.60**
Error	33	41.17	1.25	1.00
Bulk density	5	1,367.00	273.40	219.16**
Depth	1	56.33	56.33	45.16**
Bulk density x depth	5	40.67	8.13	6.52**
Error	33	41.17	1.25	1.00

C.V. = 7.14 %, **Significant at 1 % level

	SED	CD (P = 0.05)	CD (P = 0.01)
Bulk density	0.56	1.14	1.53
Depth	0.32	0.66	0.88
Bulk density x depth	0.79	1.60	2.16

cm was favourable for germination of black gram and cotton, whereas, germination was best for maize and gingelly at a seeding depth of 5.0 cm and 2.0 cm respectively.

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Table 5 Interaction of treatment combination on germination

Bulk density ($g\ cm^{-3}$)	Average black gram germination (No.)		Average maize germination (No.)		Average cotton germination (No.)		Average gingelly germination (No.)	
	2.5 cm	5.0 cm	2.5 cm	5.0 cm	2.5 cm	5.0 cm	2.0 cm	3.0 cm
Control	15.00	11.50	7.00	6.75	8.75	7.50	16.75	15.50
1.1	19.00	17.00	7.25	7.75	11.75	5.75	28.25	24.50
1.2	18.25	15.00	9.75	12.25	8.00	4.75	19.75	19.50
1.3	28.00	20.00	4.25	7.50	6.75	3.50	14.75	13.50
1.4	17.50	13.75	6.75	4.75	4.75	2.75	13.50	12.50
1.5	15.25	10.50	4.00	3.25	4.00	2.75	12.50	7.00
Mean	18.83	14.62	6.33	7.04	7.33	4.50	17.58	15.41

Testing, Evaluation and Modification of Manual Coiler for Drip Lateral

by

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Abstract

A manual coiler was developed in the Dept. of Farm Power And Machinery CAET Dr. P.D.K.V. Agril. University, Akola (M.S.) India to overcome the difficulty in coiling and decoiling operations during laying and removal of drip laterals. However, testing identified the need for modifications which were made. The machine was tested for its performance with a 150 m long segment of drip lateral in the field (black-cotton soil with a bulk density of 1.12 gm/cc and moisture content near field capacity). Also, it was tested for its cost. The machine performance was good in terms of field capacity, field efficiency energy conservation, and reduction of cost and drudgery. Therefore it could be adopted in advanced farming.

Introduction

India must increase its irrigation potential from 42 % to 50 % by 2000 A.D. to satisfy the immense demand for food. (Jain, 2002). Micro-irrigation is not merely an irrigation technology, but an integrated management tool in the hands of the farmer. Water saving is one of its prominent features along with other consequential advantages. Micro-irrigation can save water by 39 % to 62 % with an increase of production by 2 to 4 times and productivity by 27 % to 52 %. It can easily achieve irrigation efficiency of 90 % to 95 % as compared to 30 % to 35 % with flood irrigation, so it is most often used worldwide (Jain, 2002). Installation and removal of a drip irrigation system is a drudgerous and cumbersome job requiring many man-hours. The laterals are available in the form of coils and coiling and decoiling operations must be performed in the field. Also, the rough handling, scaring, twisting, folding and pitting of the lateral tend to reduce the life. To overcome such difficulty, a simple, low-cost, manual, coiling-decoiling machine was designed and fabricated in the Dept. of Farm Power and Machinery Dr. P. D. K. V. Agril. University Akola (M.S.) in 1998. Operation of the original machine showed that there was an need for modification and reevaluation. Thus, the following objectives were identified for this study -

1. To modify the coiler as required.
2. To test the machine for field performance.
3. To evaluate the machine for its initial and working cost.

Working of the Machine

The machine was stationary during its operation, while the reel mounted over it was able to rotate through 3600 around the central shaft provided. The machine had two operations, namely, 'coiling and de-coiling'. In the coiling operation, the starting end of the drip lateral was hooked to the reel of the coiler,

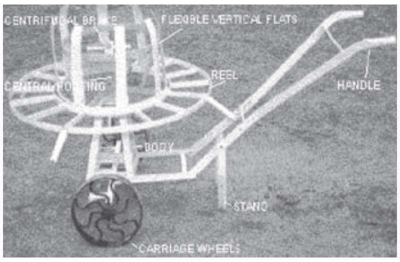

Fig. 1 Side view of the coiler

and then rotated until the complete segment of the drip lateral was coiled. During de-coiling, the coil of the drip lateral was mounted over the reel and one end was pulled by walking in the field along the line over which the coil was to be laid. In both of these operations, the machine was stationary and not in the field, which is an advantage.

Materials and Methods

The original model was constructed in the laboratory and a cost analysis was made. It was then tested for field performance. When modifications were incorporated the machine was re-tested and compared with the original machine.

An area 1.5 ha at the North-East corner of CAET Dr. PDKV Akola (M.S.) India was selected for the study. It was 150 m long by 100 m wide with black cotton soil having a bulk density of 1.2 gm/cc. Experiments were conducted with soil moisture near field capacity to obtain maximum values of force required for the operation (Heish, 1994).

A 150 m long H.D.P.E. drip lateral having a diameter of 16 mm was loaded on the reel of coiler. A person pulled the free end of the coil and a proving ring measured the pull required for the decoiling operation. The lateral was laid in the field for its full length. The coiling operation was begun by hooking the lateral to the appropriate place on the reel. The reel was rotated at an approximate constant speed. A proving ring was used to measure the torque.

A constant row-to-row width of 1m was assumed and field capacities and field efficiencies for the machine were calculated in tilled and untilled field conditions at a soil moisture near field capacity.

Machine Modifications: During de-coiling operation of the original machine, the inertia of the system increased after de-coiling of the first 30 m segment. The extra force required to overcome this inertia caused the reel to temporarily turn faster than the lateral was moving and resulted in a spilling out of the coil from the vertical flats provided. To overcome this problem, a centrifugal brake was designed to reduce the abnormal increase in the speed.

Centrifugal Brake: The brake was designed similar to the design of the centrifugal governor system of Khurmi (2001) with modifications.

A vertically mounted drum of 200 mm diameter was made up of a M. S. plate. Two iron balls of 90 gm each were attached to the rotating reel bearing- housing by means of two springs having a stiffness of 0.1 kN/m each. As the speed of rotation increased, the centrifugal force acting on the balls pushed them away from the center of rotation, so that they slid against the brake drum, which was stationary. The sliding friction caused reduction in the speed, which prevented the problem discovered earlier.

The modified machine was tested in the field using the following parameters.

1. Moisture content of the field at the time of each test as per the standard procedure given in the literature (Punmia, 2001).
2. Speed of the operation.
3. Effort required for coiling and de-coiling operations.
4. Field capacity and field efficiency of the machine before and after incorporation of modifications in differing field conditions (Kepner, 1987).
5. Total market cost of the machine.
6. Working cost of the machine (Kepner, 1987).

Construction of the Coiler

The modified coiler is shown in **Fig. 1**.

Reel: The reel was made of three concentric rings with diameters of 500 mm, 550 mm and 900 mm respectively. These rings were joined with equally spaced straight M.S. plates and the whole machine was mounted horizontally on a shaft having its longitudinal axis in the vertical direction by means of central housing. The space between the first two rings (2.5 mm) served as the trap for holding the starting end of the lateral at the time of coiling. Also there were four arms provided along its periphery, which served as

Longitudinal length of the shaft	First 30 mm length	Next 30 mm length	Next 30 mm length	Next 30 mm length
Diameter of the shaft	25 mm	15 mm	25 mm	12.5 mm

Table 1 Varying diameters of central supporting shaft

Test condition	Initial wt. of soil and box (W_2), gm.	Wt. of box (W_1), gm.	Final wt. after oven-drying of soil and box (W_3), gm.	Moisture content, %
Untilled	220	20	172	31.58
Tilled	220	20	178	27.58
Tilled with modified machine	220	20	178	27.58

Table 2 Moisture contents at the time of field tests

handles.

Flexible Flats: Eight vertical flats of 300 mm length each served as a core for the coils. They were welded vertically to the ring having a diameter of 500 mm. For easy de-coiling operation, these flats were bend inward at the height of 200 mm from the base.

Support of the Flexible Flats: During coiling, the drip lateral applied pressure to cause inward bending of the flexible flats. To prevent this, a supporting concentric ring was provided on the shaft, which had a diameter of 450 mm and was held at 200 mm above the base of the flats at uniform distance of about 25 mm from each vertical flat.

Central Supporting Shaft: A M. S. shaft of 230 mm length with a varying diameter was welded to the frame and the inner bearing race so that the core of the reel was mounted on the outer race of the bearing, which was free to rotate. The varying diameters provided to the shaft along its longitudinal axis are shown in **Table 1**.

Body: The structure that rested over the carriage wheels was made of angle iron bars. It had upper-face dimensions of 150 mm x 150 mm and lower face dimensions of 220 mm x 220 mm. Slanting angled iron bars joined both faces. The overall height of the body was 300 mm with a clearance of 30 mm between reel and the upper face of the body.

Carriage Wheels: The wheels were made of M.S. flats 40 mm wide with a circular diameter of 300 mm. They were mounted over a shaft by means of bosses. The rim was connected with the boss by means of eight ‘s’ shaped rods 10 mm in diameter. The wheel track was 750 mm.

Handle: A handle was provided to improve comfort of transportation by increasing steering ability of the machine. It could be used as either a push or pull type. It was made of two flat bars, which were connected to the housing of the wheel shaft. The flats were bend upward and joined together by means of a horizontal rod (to increase its rigidity).

Stand: Two 40 mm (5 mm vertical M.S. flats having length of 110 mm. They were provided to support the whole machine when it was in the rest position. These flats were attached vertically to the handle.

Dimensions of all the components obtained along with their individual costs were as shown in **Table 9**.

Results and Discussion

Field Testing

The results obtained during the field-testing of the equipment were as shown in **Table 5** to **Table 8**.

Cost Analysis

If the profit = 20 %

Then, Selling price = (0.2 x 3400) + 3400 = 4080 ≈ 4100.

Operating Costs

Machine costs:

1. Let labour charges (L) = Rs. 6.25/hr.

2. Depreciation cost (D) = (C-S) ÷ (L x H)

Length of lateral de-coiled (m)	Test conditions								
	Untilled soil with unmodified machine			Tilled soil with unmodified machine			Tilled soil with modified machine		
	Time required (sec)	Average pull (kg)	Speed (m/sec)	Time required (sec)	Average pull (kg)	Speed (m/sec)	Time required (sec)	Average pull (kg)	Speed (m/sec)
150-120	13	1.24	2.31	14	1.4	2.14	16	1.40	1.88
120-90	17	3.06	1.76	16	3.25	1.88	18	1.25	1.67
90-60	19	4.5	1.58	20	5.6	1.5	21	5.82	1.43
60-30	18	5.54	1.67	22	6.5	1.36	21	6.54	1.43
30-0	19	6.21	1.58	22	7.8	1.36	22	8.0	1.36
Total	∑ 86			∑ 94			∑ 98		

Table 3 Observations obtained during de-coiling operations

Length of lateral de-coiled (m)	Test conditions											
	Untilled soil with unmodified machine				Tilled soil with unmodified machine				Tilled soil with modified machine			
	Time required (sec)	No. of turns required	Average twisting force required (kg m)	Speed (m/sec)	Time reqired (sec)	No.of turns required	Average twisting force required (kg m)	Speed (m/sec)	Time reqired (sec)	No.of turns required	Average twisting force required (kg m)	Speed (m/sec)
0-30	72	19	5.2	0.42	74	19	5.6	0.41	78	20	5.9	0.38
30-60	68	18	4.9	0.44	70	18	5.2	0.43	70	18	5.15	0.43
60-90	68	14	4.2	0.44	65	13	4.6	0.46	66	15	4.39	0.45
90-120	60	13	3.67	0.50	60	13	4.0	0.50	60	12	3.88	0.50
120-150	48	12	1.27	0.63	51	14	3.4	0.59	55	12	1.5	0.55
Total	∑ 316				∑ 320				∑ 329			

Table 4 Observations obtained during coiling opwrations

Where,

C = Initial value of the machine.

S = Salvage value of the machine.

H = Life of the machine in years (13 years).

L = Working hours per year of the machine (100 hours).

D = (4300-430) ÷ (13 x 100) = Rs. 2.98 ≈ Rs. 3.

3. Interest (I) = ((C+S) ÷ 2) + (i ÷ H)

Where,

i = interest rate = 12 %

I = ((4300+430) ÷ 2) + (0.12 ÷ 100) = Rs.2.84 ≈ Rs. 3.

Therefore, variable cost per hour (T) = L + D + I = 6.25 + 3 + 3 = Rs. 12.25.

[I] De-coiling operation = Field capacity = 0.45 ha/hr.

So, operational cost in de-coiling operation = Rs. 27.22/ha. ≈ Rs. 27.25/ha.

[II] Coiling operation = Field capacity = 0.13 ha/hr.

So, operational cost in coiling operation = Rs. 94.23/ha. ≈ Rs. 94.25/ha.

Cost Involved in Traditional Method:

It was observed, that field capacity of two labours for de-coiling operation was about 0.20 ha/hr and that of coiling was about 0.10 ha/hr. So, one labour hour costs Rs. 6.25.

(a) De-coiling operation = 2 x 6.25 ÷ 0.20 = Rs. 62.50/ha.

(b) Coiling operation = 2 x 6.25 ÷ 0.10 = Rs. 125.00/ha.

Conclusions

The following conclusions were drawn from the study:

The machine was stationary during its operation and had no need to enter the field. Thus the soil and the crop were not disturbed, which was especially important when the soil moisture content is high.

During the de-coiling operation the average speed of operation was 1.53 m/sec with a maximum pull requirement of 8 kg for the modified machine. The actual field capacity of the operation was 0.45 ha/hr with a field efficiency of 81.82 %. When these values were compared with values for the unmodified machine over same field conditions, the modified machine showed negligible reduction in operational speed and actual field capacity but a slight increase in the pull requirement due to friction of brake provided and that is permissible.

The coiling operation for the modified machine showed a maximum twisting force of 5.9 kg/m with a speed of operation of about 0.46 m/sec and actual field capacity and field efficiency of 0.13 ha/hr. and 81.25 % respectively for the coiling operation. As compared to the unmodified machine, the speed of operation and actual field capacity were slightly reduced while twisting force requirement was slightly increased which is permissible.

The total cost of the modified machine was found to be Rs. 4100 with an operational cost of Rs. 12.25/hr. The operational costs of coiling and de-coiling operations were found to be Rs. 94.25/ha and Rs. 27.25/ha respectively. This was much less than the operational costs involved in traditional method, which were found to be Rs. 125/ha and Rs. 62.50/ha in coiling and de-coiling operations respectively.

So, it was concluded that the machine was quite economical and adaptable in the present era of efficient irrigation management.

Test conditions	Average speed of operations (m/sec)	Maximum pull required (kg)
Untilled soil with unmodified machine	1.74	6.21
Tilled soil with unmodified machine	1.60	7.80
Tilled soil with modified machine	1.53	8.00

Table 5 Results of working speed and maximum force required obtained for de-coiling operation

Test conditions	Average speed of operations (m/sec)	Maximum twisting force required (kg)
Untilled soil with unmodified machine	0.47	5.2
Tilled soil with unmodified machine	0.47	5.6
Tilled soil with modified machine	0.46	5.9

Table 6 Results of working speed and maximum twist required obtained for coiling operation

Test conditions	Theoretical field capacity (ha/hr)	Actual field capacity (ha/hr)	Field effiency (%)
Untilled soil with unmodified machine	0.63	0.52	82.54
Tilled soil with unmodified machine	0.58	0.46	79.31
Tilled soil with modified machine	0.55	0.45	81.82

Table 7 Field capacities and field efficiencies for de-coiling operation

Test conditions	Theoretical field capacity (ha/hr)	Actual field capacity (ha/hr)	Field effiency (%)
Untilled soil with unmodified machine	0.17	0.14	82.35
Tilled soil with unmodified machine	0.17	0.14	82.35
Tilled soil with modified machine	0.16	0.13	81.25

Table 8 Field capacities and field efficiencies for coiling operation

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Table 9 Dimension and cost of individual component on material required

Item	Specifications (mm)	Length (m)	Weight (kg)	Amount (Rs.)
Carriage wheel				
Rim	50 x 5	2.5	5	50
Spoke	12 ø	4.4	2.7	45
Boss	50 ø	0.15	2.5	50
Axle	30 ø	1.5	12	180
Vertical support to reel shaft				
MS. angle	35 x 35 x 5	2.5	4	65
MS. shaft	30 x 5	0.3	4	65
Reel shaft				
Round bar	35 ø	0.25	2.5	55
Bearing (30206)	1-in no.	-	-	125
Bearing (30205)	1-in no.	-	-	100
Nuts	12.75	-	-	10
Reel spindle				
MS. pipe	70 ø	0.25	-	40
MS. bar	70 ø	0.2	4	60
Reel				
MS. flat	30 x 5	14	18	290
MS. pipe	25 ø	0.4	-	40
Reel core leaf				
MS. pipe	300	0.25	-	300
Handle and stand				
MS. flat	40 x 50	3.10	-	50
MS. flat	25 x 5	3.00	-	50
Centrifugal brake				
MS. bar	16 ø	0.10	-	320
MS. sheet	31,000 mm^2	10 gauge	-	50
Miscellaneous				
Nuts and bolts	-	-	-	250
Primer	-	-	-	100
Colour	-	-	-	100
Labour	-	-	-	500
Electricity and other consumable charges	-	-	-	500

Total amount = Rs. 3395 ≈ Rs. 3400

Single Hydrocyclone for Cassava Starch Milk

by

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Abstract

Washing, rasping and screening operations in the processing of cassava, require a large quantity of water, which leads to the production of more volume of starch milk. Conventionally, starch separation from milk is being carried out by the gravity settling method. The longer contact time of water with starch leads to the fermentation producing alcohols and organic acids which gives very bad smell and pollutes the whole atmosphere surrounding the industry. This paper describes the single hydrocyclone developed to concentrate the starch milk for a more rapid separation of starch from fruit water. The water can then be recycled to reduce the consumption and the volume of effluent from the factory. A prototype single hydrocyclone of 101.6 mm (4 inches) diameter was developed and fabricated with 1 mm GI sheet. The performance of the hydrocyclone was evaluated at two inlet diameters (34.5 mm and 19 mm), two overflow diameters (34.5 mm and 19 mm), three under flow diameters (8.6 mm, 7 mm and 5 mm), five pressure levels (9.8 KPa, 19.6 KPa, 29.4 KPa, 39.2 KPa and 49 KPa) and ten feed concentrations (3, 5, 7, 9, 11, 13, 15, 17, 19 and 21 percent).

A maximum underflow concentration of 43 percent was obtained when the feed was at 21 percent concentration at the highest pressure (49 Kpa), the lowest overflow diameter (19 mm), the lowest inlet diameter (19 mm) and an under flow diameter of 5 mm. Since the concentration of starch milk coming to the settling tank is 5 percent in the existing factories, the developed hydrocyclone was optimized for 5 percent feed concentration. The optimized parameters were: cyclone diameter of 101.6 mm, inlet diameter of 19.0 mm, overflow diameter of 19.0 mm, length of vortex finder of 40.6 mm, underflow diameter of 5.0 mm, length of cylinder of 84.7 mm and length of cone of 423.3 mm.

Introduction

Washing, rasping and screening operations in processing of cassava require a large quantity of water, which leads to the production of more volume of starch milk. Conventionally, starch separation from milk is being carried out by the gravity settling method. The starch and sago factories are adopting outdated technology that involves longer duration of extraction and unhygienic handling of the material leading to a poor quality end product (Rangaswami, 1993). The longer contact time of water with starch leads to the fermentation producing alcohols and organic acids (Radley, 1976). The effluent from the sago processing units with high organic matter creates environmental pollution around the factories (Belliappa, 1990). The starch milk is permitted to settle for 6-8 hours in a tank with out disturbance. Sreenarayana et al. (1990) reported that a rapid separation of starch from the milk and the removal of impurities from the colloidal suspension could be achieved by centrifuging. But centrifuging could not completely replace the gravity settling, and settling was to be employed after centrifuging to separate the starch from any other remaining solid impurities. A hydraulic jack can be used as a dewatering technique by pressing with the water being removed by powerful mechanical pressing equipment (Igbeka et al., 1992).

In order to separate water from the starch milk, a hydrocyclone system would be preferable. A preferable method for starch milk separation would be a hydrocyclone system. The majority of the solid particles are concentrated into a smaller volume of water and exit at the bottom of the cyclone called the underflow. Excess water is removed from the top of the hydrocyclone called the overflow. The concentrated starch milk from the bottom of the hydrocyclone can be directed to the settling tanks and the excess water can be recycled for crushing the fresh tubers.

Materials and Methods

Hydrocyclone

Classifying cyclones are a widely used device for achieving ultra fine particle size separations in industrial applications (Honaker et al., 2001). Hydrocyclones have received recent

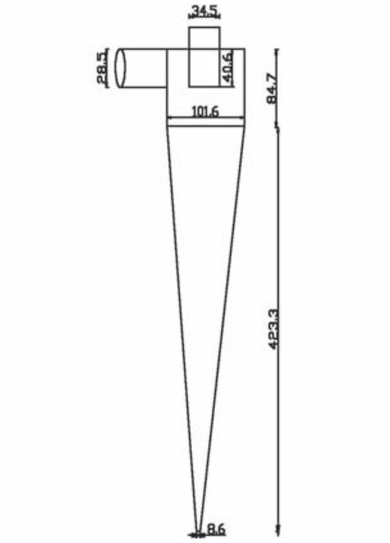

Fig. 1 Experimentally developed hydrocyclone

attention because of advantages such as simple structure, low cost, large capacity and small volume. The hydrocyclone separation technique has been used in an increasing number of recent applications in areas such as mineral processing, environmental engineering, petrochemical engineering, food engineering, electrochemical engineering, bio engineering, and pulping process. (Liang Yin Chu et al. 2002).

Hydrocyclones were originally designed to promote solid-liquid separations but are now used for solid-solid, liquid-liquid and gas-liquid separations. A hydrocyclone has no moving parts and consists of a conical section joined to a cylindrical portion, which is fitted with a tangential inlet and closed by an end plate with an axially mounted overflow pipe. The end of the cone terminates in a circular apex opening. Although a hydrocyclone is very simple to build, custom-made cyclones are not widely used. This is probably due to the lack of a simple procedure for hydrocyclone design (Castilho and Medronho, 2000). Tangential fluid feeding, causes a strong rotational movement inside the equipment that charges a centrifugal field. Because of this field, the solid particles are suspended in the fluid and tend to move towards the wall. The high tangential velocity of the fluid in the central part of the device causes the pressure to decrease below atmospheric pressure. The low-pressure region causes the formation of an air core in the central line. Generally, the heavier material moves to the periphery (by centrifugal force) and falls to the bottom and exits with some carrier fluid. Most of the carrier fluid and some of the lighter material moves to the low pressure section in the central line and to the exit. In spite of the simple geometry and operation, explaining the detailed mechanism of the work is extremely complicated (Romero and Sampaio, 1999). Although traditional orientation of a classifying hydrocyclone is vertical, some hydrocyclones are mounted inclined to the vertical, and in extreme cases can even be essentially horizontal. This is often done for plant design or installation convenience rather than for process reasons, but it would be expected that the performance of an inclined cyclone would be different to that of a vertical unit, especially for large, low pressure cyclones (Asomah and Napier Munn, 1997). The magnetic cyclone was developed in the late sixties as a natural extension of a conventional hydrocyclone with the aim of providing an additional external (magnetic) force to supplement the gravitational and centrifugal forces that cause classification and separation (Svoboda et al., 1998).

In operation, the starch milk consisting of particles of starch suspended in water is introduced tangentially into the cylindrical portion. The high centrifugal force acting on the starch particles throw these to the walls, whilst the lower gravity fluid passes to the low pressure in the center. The starch particles pass via the cyclone walls to an opening at the apex of the cone, where they are discharged. The fluid passes to a tangential overflow at the opposite end of the hydrocyclone by way of a tube that projects into the vortex of the cone from the top. Contrasting with gas cyclones, for which there are several families of geometrically similar cyclones, there are only two well-known families of geometrically similar hydrocyclones, these are due to Rietema and Bradley. Bradley hydrocyclones provide higher efficiencies, while Rietema hydrocyclones give higher capacities (Castilho and Medronho, 2000).

The following dimensions, as recommended by Rietma and Verver, (1961) for the standard hydrocyclone, were taken for the fabrication of the experimental hydrocyclone.

$L/D = 5$ ....(1)

$l/D = 0.4$ ....(2)

$b/D = 0.28$ ....(3)

$D_o/D = 0.34$ ....(4)

$D_u : D_o = 1 : 4$ ....(5)

$L_1 : L_2 = 1 : 5$ ....(6)

Where,

L = Cyclone length

D = Cyclone diameter

l = Length of vortex finder

b = Inlet diameter

D_o = Diameter of overflow orifice

D_u = Diameter of underflow orifice

L_1 = Length of cylindrical portion and

L_2 = Length of cone.

A 101.6 mm (4 inches) hydrocyclone (cyclone diameter) was designed and fabricated with 1.0 mm galvanized iron sheet. The fabricated hydrocyclone had the following specifications

Cyclone diameter: 101.6 mm

Inlet diameter: 28.5 mm

Diameter of overflow orifice: 34.5 mm

Length of vortex finder: 40.6 mm

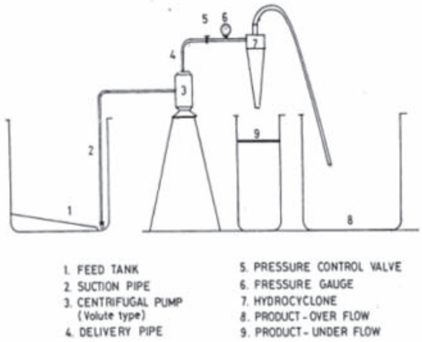

Fig. 2 Experimentally set up of hydrocyclone unit for starch milk concentration

Underflow orifice diameter: 8.6 mm
Length of cylinder: 84.7 mm
Length of cone: 423.3 mm

The details of the developed hydrocyclone are given in **Fig. 1**.

Experimental Set up

The experimental set up for the performance evaluation of the developed hydrocyclone is given in **Fig. 2**. A centrifugal pump of 1 hp, was selected for pumping the feed pulp. Starch milk with different concentrations was prepared in a tank. A 38.1 mm pipe with foot strainer was used as suction pipe for the centrifugal pump. Using a 38.1 mm to 19.0 mm reducer a 19.0 mm delivery pipe was connected to the centrifugal pump. A pressure control valve and pressure gauge were connected in the delivery pipe. The other end of the delivery pipe was connected to the inlet of hydrocyclone. Overflow product was collected from the vortex finder through a flexible hose pipe in a cement tank. Underflow product was collected in a graduated bucket.

The developed hydrocyclone was tested at five different pressure levels, with two different inlet diameters and overflow diameters and three different underflow diameters. The feed concentration was varied from 3 percent to 21 percent. Different feed concentrations were achieved by adding dry starch flour with a known volume of water. Hydrocyclone parameters were altered by using different sizes of pipe for the inlet, overflow and under flow as shown below.

I_1: Inlet diameter = 28.5 mm
I_2: Inlet diameter = 19.0 mm
O_1: Overflow diameter = 34.5 mm
O_2: Overflow diameter = 19.0 mm
U_1: Underflow diameter = 8.6 mm
U_2: Underflow diameter = 7.0 mm
U_3: Underflow diameter = 5.0 mm
Pressure levels: 9.8 KPa, 19.6 KPa, 29.4 KPa, 39.2 KPa and 49 KPa

Experimental Design

Factorial completely randomized design (FCRD) was used. Since starch milk is coming at 5 percent concentration to the settling tank in the existing sago factory, experimental results obtained at 5 percent feed concentration were alone taken for statistical analysis.

Independent factors: I_1, I_2, O_1, O_2, U_1, U_2, U_3 and five different pressure levels.

Dependent factor: Underflow concentration.

The experiment was replicated three times.

Performance Evaluation

The hydrocyclone was evaluated by observing the underflow concentration with different feed concentrations, inlet diameter, overflow diameter, underflow diameter and pressure. The percent increase in underflow concentration was calculated by the equation.

Percent increase in underflow concentration = $\{((C_u - C_f) \times 100)/ C_f\}$..(7)

Where,

C_f = feed concentration in percent and

C_u = underflow concentration in percent

Results and Discussion

Percent Increase in Underflow Concentration

In general, there was an increase in the underflow concentration when the feed concentration was increased. When the particle density or the particle size increasesd, the absolute radial velocity of the solid particles decreased. The particle radial velocity also decreased with increasing the feed particle concentration (Lian Yin Chu et al., 2002). The underflow concentration also increased with increase in pressure and with the reduction in the overflow diameter, underflow diameter and inlet diameter. A maximum underflow concentration of 43 percent was obtained at the highest pressure of 49 KPa, the lowest overflow diameter, inlet diameter and underflow diameter of 19 mm,

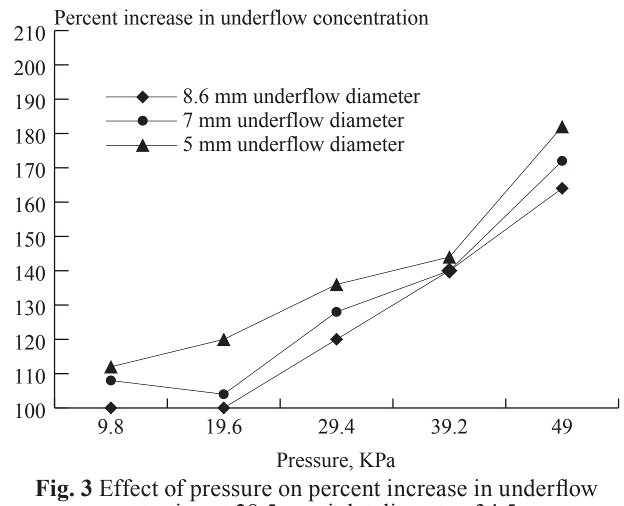

Fig. 3 Effect of pressure on percent increase in underflow concentration at 28.5 mm inlet diameter, 34.5 mm overflow diameter and 5 percent feed concentration

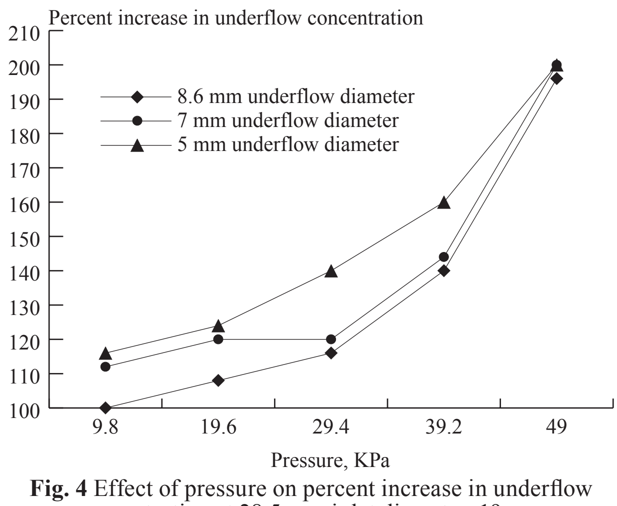

Fig. 4 Effect of pressure on percent increase in underflow concentration at 28.5 mm inlet diameter, 19 mm overflow diameter and 5 percent feed concentration

19 mm and 5 mm respectively when the feed was at 21 percent concentration. Effect of pressure on percent increase in underflow concentration at different inlet diameters and outlet diameters of hydrocyclone are presented in **Fig. 3** to **Fig 6**. As pressure increased, the percent increase in underflow concentration also increased for all underflow diameters. At 28.5 mm inlet diameter and 34.5 mm overflow diameter, the maximum percent increase of 182 in underflow concentration was obtained. It was observed that reduction in the underflow diameter of the cyclone increased the percent increase in the underflow concentration. It was revealed from **Fig. 4** that, when the overflow diameter of 19 mm was used, the maximum percent increase obtained was 200. The increase in pressure increased the percent increase in underflow concentration. The maximum percent increase in underflow concentration obtained at 19 mm inlet diameter was 202, where as only 182 percent increase in underflow concentration could be obtained at 28.5 mm inlet diameter.

It was noted from **Fig. 6**, that a maximum percent increase of 206 in underflow concentration was obtained at 490.5 KPa pressure. The effect of pressure on percent increase, as identified in **Fig. 3** to **Fig. 6**, is summarized below.

1. As pressure increased, the per cent increase in underflow concentration also increased
2. At the lowest underflow diameter of 5 mm, the percent increase in underflow concentration was the highest at the all pressures (further reduction in underflow diameter led to the blocking of underflow).
3. The percent increase in underflow concentration was the highest when the overflow diameter and the inlet diameter were minimum.
4. The percent increase in underflow concentration was at higher rate when the inlet diameter was minimum. This might be due to the increase in the radial acceleration of solid particles when there is a reduction in the entrance orifice of the hydrocyclone (Whitcomb, 1964).

Variation of Underflow Rate

The underflow rate decreased with increases in pressure and overflow diameter. At each pressure level, the underflow rate increased with increase in underflow diameter. The variation in underflow rate with respect to overflow orifice diameter was significant at low-pressure levels and maximum inlet diameter. But this variation was marginal with higher pressure and small inlet diameters. It was also observed that there was no significant change in underflow rate with feed concentration. Patil and Rao (1999) found that with a smaller volume of underflow water there was less fines and better sharpness of separation.

Variation of Overflow Rate

The overflow rate increased with increase in pressure. It was also increased with decrease in underflow diameter. There was no significant relation between overflow rate and feed concentration.

Analysis of Variance of Factors

Since the values of underflow concentration were expressed in percent, square root transformation was made before the analysis. All individual factors, namely, underflow diameter, overflow diameter, inlet diameter and pressure had significant effect on underflow concentration (**Table 1**). The interaction of O x P, I x P and O x I x P had a significant effect on underflow concentration. The remaining interaction effect between various combinations had no significant effect on underflow concentration.

Effect of Inlet Diameter and Pressure on Under Flow Concentration

An inlet diameter of 19.0 mm was superior to 28.5 mm at all pressure levels. The combination of 19 mm diameter and 49 Kpa pressure was best.

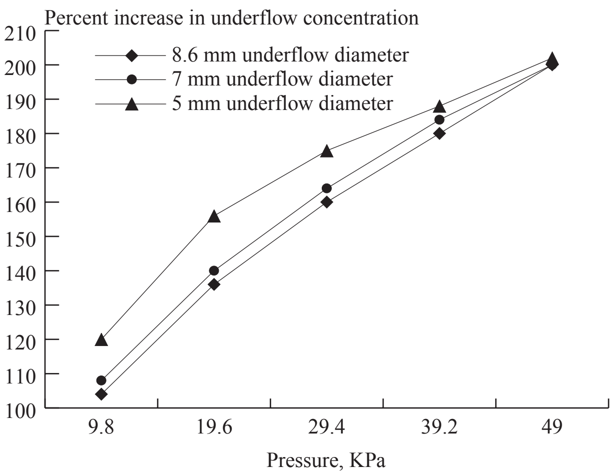

Fig. 5 Effect of pressure on percent increase in underflow concentration at 19 mm inlet diameter, 34.5 mm overflow diameter and 5 percent feed concentration

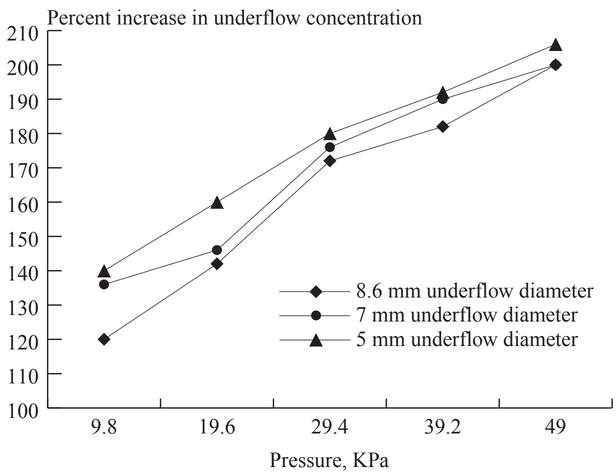

Fig. 6 Effect of pressure on percent increase in underflow concentration at 19 mm inlet diameter, 19 mm overflow diameter and 5 percent feed concentration

Effect of Overflow Diameter and Pressure on Under Flow Concentration

At both overflow orifice diameters, underflow concentration increased with increase in pressure. An overflow diameter of 19.0 mm was better than 34.5 mm. It is found that the best combination was an overflow diameter of 19.0 mm with a pressure of 59 Kpa.

Effect of Overflow Diameter (O), Inlet Diameter (I) and Pressure(P) on Under Flow Concentration

There was no significant difference between $O_1I_1P_1$ and $O_1I_1P_2$. It was noted that P_5 was superior to other pressures on underflow concentration. At O_1I_2, the pressure P_3 was on par with P_4, where as at O_1I_1, significant difference existed between P_3 and P_4. While comparing the two levels of overflow diameter with pressure and inlet diameter, O_2 was superior to O_1 at all P x I combinations. It was concluded that $O_2I_2P_5$ was the best among the various combinations of O, P and I. Since the concentration of starch milk coming to settling tank is 5 percent in the existing factories, the developed hydrocyclone was optimized for 5 percent feed concentration and the optimized parameters are: cyclone diameter of 101.6 mm, inlet diameter of 19.0 mm, overflow diameter of 19.0 mm, length of vortex finder of 40.6 mm, underflow diameter of 5.0 mm, length of cylinder of 84.7 mm and length of cone of 423.3 mm.

SV	DF	MS
Treatment	59	0.15**
Uflow (U)	2	0.18**
Oflow (O)	1	0.23**
Inlet (I)	1	1.58**
Pressure (P)	4	1.55**
U x O	2	0.00ns
U x I	2	0.00ns
U x P	8	0.01ns
O x I	1	0.01ns
O x P	4	0.01*
I x P	4	0.08**
U x O x I	2	0.00ns
U x O x P	8	0.00ns
U x I x P	8	0.00ns
O x I x P	4	0.14**
U x O x I x P	8	0.01ns
Error	120	
Total	179	

Table 1 The analysis of variance table for underflow concentration (percent) based on transformed values

Conclusions

Hydrocyclones can be used to concentrate the starch milk in cassava starch processing industries. But a single hydrocyclone could not replace the starch settling tanks in the existing factories. Starch milk from both underflow (high concentration) and overflow (low concentration) should be allowed to settle in two different tanks. In order to eliminate the settling tanks, further research should be carried out with multiple hydrocyclones. From the experiments on a single hydrocyclone for starch milk concentration, it was found that the underflow concentration increased with increase in input pressure and decrease in underflow diameter, overflow diameter and inlet diameter.

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Utilization Pattern of Power Tillers in Tamil Nadu

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Abstract

The utilization pattern and performance of selected, popular makes of power tillers were investigated in the Gobichettipalayam region of the Erode district. Selection of study areas and power tiller respondents were made by statistical procedures. All the required primary data were collected by personal interview with the help of a pre-tested comprehensive interview schedule. The data were analyzed through a percentage analysis, pooled average method and conclusions were drawn. The average annual working hours of all the makes of power tillers were in the range of 853 to 888 hours. Besides land preparation, the maximum use of the power tiller was for weeding (78.47 percent), followed by transport (55.55 percent), pumping (25.69 percent) and threshing (23.61 percent). The major accidents occurred with the engagement of the rotary tiller while crossing the bunds (91 percent) followed by road transport (84 percent). Eighty per cent of the respondents said that they were getting spare parts on time. Among the power tiller respondents surveyed, 45.83 percent had education up to middle school level, 35 percent had higher secondary level and more, and the remaining were illiterate. Fifty six per cent of the 'medium farmers' category (2-4 ha) preferred purchasing the power tiller followed by small category farmers. The priorities considered for the purchase of a power tiller, were timeliness of operation, multipurpose use, non-availability of labour and low purchasing cost. The respondents surveyed had Shrachi (water-cooled), Mitsubishi (Air-cooled) and Mitsubishi (water-cooled) power tillers.

Introduction

India is an agricultural country and agriculture contributes about 38 percent to the nation's gross domestic product. Agricultural implements and equipment are one of the major inputs in the crop production industry. They reduce drudgery involved in the farming operations, increase production and productivity, and make cumbersome work easier, more timely and more efficient. Agricultural productivity is linked with the availability of farm power. Bullocks meet power requirements of marginal and small farms (less than 2 ha) with associated limitations. Tractors meet requirements of large farms (above 6 ha). Power tillers are visualized as an appropriate source of farm power for medium farms (2 -6 ha).

The power tiller is a multipurpose walking tractor designed for rotary tilling and other farm operations where the operator walks behind. Its maneuverability and versatility make it ideally suited for various agricultural operations in small and medium size farm holdings of both dry lands and irrigated lands. Tamil Nadu accounts for 17.45 percent of the total power tillers available in India. At present, the power tiller is mainly used for rotary tilling, ploughing, and puddling in dry land, garden land and wet land. A study to identify the soil, cropping pattern and region will be of great use to the power tiller owner and the manufacturer so that the power tiller can be most effectively utilized during its lifetime. In this investigation, the utilization and performance of power tillers are analyzed through surveys and collection of basic data with a pre-tested interview to identify the problems and constraints encountered by the users.

Review of Literature

Singh (1987) found that farmers owning power tillers had more land and operational holdings than farmers not owning power tillers. Pacharne et al. (1990) reported that 90 percent of power tiller owners used them for paddy crop, 35 percent for inter-cultivation in orchards and 43 percent for commercial purposes. Most of the farmers were satisfied with the use of power tillers for farm work. Varshney et al. (1990) stated that the power tiller was used for transportation of tree seedlings, digging pits, plant residue collection and tree felling in forestry. Dash et al. (1993) observed that power tiller farming system was superior to bullock farming system considering the yield and cost of operation. Dash et al. (1990) concluded that rota puddling twice using a power tiller was found to be the best in terms of depth and speed of operation, time requirement, fuel consumption, grain yield and straw yield. Uddin (1991) reported that puddling operation by power tiller was the more energy saving as compared to the bullock and the tractor in rice cultivation.

Materials and methods

Formulation of Interview Schedule

The information on location, educational details, land holding and size, soil type, cropping pattern, details of the power tiller, operations performed with the power tiller, failure details, facilities for repair, maintenance aspects of power tiller, ergonomic aspects of the power tiller, socio economic aspects and constraints were collected through an interview schedule.

Selection of Sample

(i) Selection of the Study Area

The highest population of power tillers in 1994 was found in the Erode district of Tamil Nadu, and accounted for 16.74 percent of the total number of power tillers, according to the Department of Statistics, Chennai. Among various taluks of the Erode district, the Gobichettipalayam taluk had the maximum power tiller population and was selected for this study (**Table 1**). Three popular makes of power tillers; Shrachi (water cooled), Mitsubishi (air cooled) and Mitsubishi (water cooled) were selected..

In Gobichettipalayam taluk, the number of power tillers was maximum in the Gobichettipalayam block (318), followed by T. N. Palayam block (148) and Nambiyur block (95). Gobichettipalayam taluk has 72 revenue villages spread out in three blocks. Of the 72 villages, 50 percent (36) were selected for this study. The number of villages selected in each block was based on the proportion of the power tillers in each block. The proportion of power tillers in Gobichettipalayam, T. N. Palayam, and Nambiyur blocks were 57, 26 and 17 percent, respectively. Accordingly 20, 9 and 7 villages were selected in Gobichettipalayam, T. N. Palayam, and Nambiyur blocks, respectively, and are shown in **Fig. 1**.

The revenue villages in each block were listed based by the descending order of number of power tillers. From this, the first 20 villages in the Gobichettipalayam block, the first 9 villages in T. N. Palayam, and the first 7 villages in the Nambiyur block were selected. The list of sample villages selected are shown in **Tables 2**, **3** and **4**, respectively.

(ii) Selection of Power Tiller Respondents

A master list of farmers owning power tillers for conducting the survey was obtained from the Statistical department, Gobichettipalayam, and from the local dealers who supplied the different makes of power tillers. In each selected village, four farmers who owned the power tillers were selected randomly. The selected farmers in each village

Table 1 Taluk and block wise population of power tiller in Erode district (1994)

Taluk	Block	Power tiller population	Total
Bhavani	Bhavani	139	331 (18.46)
	Ammapatty	107	
	Anthiyur	85	
Dharapuram	Dharapuram	30	59 (3.29)
	Kundadam	10	
	Mulanur	19	
Erode	Modakuruchi	82	222 (12.38)
	Erode	78	
	Kodumudi	62	
Gobichettipalayam	**Gobichettipalayam**	**318**	**561 (31.29)**
	T. N. Palayam	**148**	
	Nambiyur	**95**	
Kankeyam	Vellakoil	48	60 (3.35)
	Kankeyam	12	
Perundurai	Chennimalai	102	214 (11.93)
	Perundurai	85	
	Uthukkuli	27	
Sathyamangalam	Bhavanisagar	170	346 (19.3)
	Sathyamangalam	129	
	Dhalavadi	47	
Total		1,793	100

were first asked whether they had purchased the power tiller before 1994. If his response was 'yes', then he was considered as a sample unit and data were collected.

Collection of Data

All the required primary data were collected from the farmers by personal interview with the help of a pre-tested comprehensive interview schedule specifically designed for this purpose. The data included information on education, land holding, field size, soil type, cropping pattern, manufacturer and model of the power tiller, utilization pattern, failure details, attitude towards the loan scheme, and their opinion and suggestions for improvement of the power tiller.

Method of Analysis

The data were classified and analyzed. The Shrachi power tiller respondents were categorized as Make A, Mitsubishi (air-cooled) power tiller respondents were categorized as Make B and Mitsubishi (water-cooled) power tiller respondents were categorized as Make C.

The topic areas and the factors covered in each topic area were:

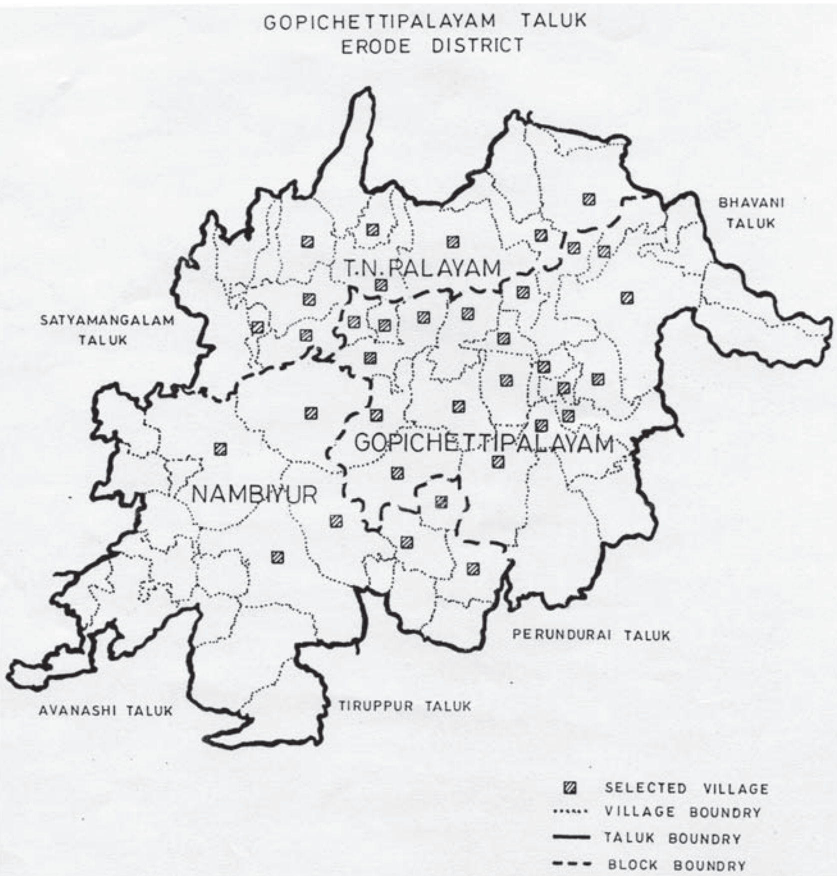
a. General characteristics of the respondent with the following factors; education, soil type, size of holding, farming experience, occupation, and bullock/tractor use.

b. Utilization of the power tiller by the respondent with the following factors; reason for purchasing the power tiller and the particular make, use of the power tiller for different operations, and operator comfort.

c. Cost and maintenance of the power tiller with the following factors; lubrication and oil change, maintenance as viewed by the respondent, and overall performance of the power tiller as viewed by the respondent.

d. Problems and constraints of the power tiller with the following factors; noise level, operational problems, accident factors, service factors, and spare parts available.

Table 1 Taluk and block wise population of power tiller in Erode district (1994)



Results and Discussion

General Characteristics of the Respondent

Among the respondents, 45.83 percent had education up to middle school level, 35 percent had higher secondary level and more and the remaining were illiterate. Of the respondents 30, 35 and 35 percent had purchased the Shrachi (water-cooled), Mitsubishi (air-cooled), and the Mitsubishi (water-cooled) power tillers, respectively.

The land holding distribution pattern was 30 percent, 26 percent and 44 percent of wet land, garden land and mixture of wetland and garden land, respectively. The majority (56 percent) of medium farmers (2-4 ha) preferred purchasing power tillers followed by small category farmers. This may be due to versatility of the power tiller for performing most of the farm operations in medium and small farms.

With respect to soil type, 76 percent had heavy soil farms and the remaining 24 percent were had light soil farms. Forty six percent of the farmers had 11-20 years farming experience and 23 percent had 21-30 years farming experience. This indicated that the power tillers sales were increased during the last two decades. About 87 percent had agriculture as their primary occupation.

Utilization of Power Tiller by the Respondent

Bullock power was predominately used for head land ploughing and the power tiller was used for other farm operations. The priorities considered for the purchase of a power tiller were timeliness of operation (49.30 percent), multipurpose use

(48.56 percent), non-availability of labour (45.13 percent) and low purchasing cost (43.15 percent). The major reasons for the purchased of the Shrachi (water-cooled) power tiller were after sale service and the provision for a seat.

Fuel efficiency, make and model availability were expressed as the major reasons for the farmers who purchased the Mitsubishi (air-cooled). The average annual working hours of all the makes of power tillers ranged from 853 to 888 hours. The Mitsubishi (air-cooled) power tiller was used for maximum hiring because of its suitability for paddy threshing.

Mitsubishi (air-cooled) and Mitsubishi (water-cooled) power tiller operators continuously operated the power tillers for a maximum of five hours and the Shrachi (water-cooled) power tiller were operated for a maximum six hours continuously. The continuous operation of power tillers was mainly dependent on experience of the operator. The Shrachi (water-cooled) power tiller had the maximum continuous operation due to the presence of a seating attachment.

All the respondents (100 percent) expressed that the power tiller was suitable for land preparation in both garden and wet land. Besides land preparation, the maximum use of the power tiller was for weeding operation (78.47 percent), followed by road transport (55.55 percent), pumping (25.69 percent) and threshing (23.61 percent). The Mitsubishi (air-cooled) power tiller alone was used for all operations including threshing because of absence of a radiator. Among the respondents 61.80 percent operated the power tiller both by themselves and by hired operators.

Cost and Maintenance Aspect of Power Tiller

The cumulative rest time required for the power tiller operator was up to one hour in a day of eight hours, which was expressed by 67 percent of the respondents. About 60 percent expressed that the performance of the power tiller was satisfactory and the remaining rated them as highly satisfactory. About 60 percent of the power tiller farmers indicated that the maintenance of the power tiller was easy and the remaining indicated that it was difficult. This indicated that training on operation and maintenance of the power tiller was necessary. The general practice of the respondents for changing the gear oil and engine oil was only during the service time of the power tiller. They were not following the recommended norms prescribed by the companies.

Problems and Constraints of Power Tiller Users

The major accidents occurred while crossing the bunds with the engagement of the rotary tiller (91 percent) followed by transport (84 percent). The same pattern was also observed in all makes of power tillers. Considering the operation of the power tiller, 59 percent of operators were of the opinion that the operation was moderate. The

Table 2 List of selected sample villages of Gobichettipalayam block

Name of sample village	Power tiller population
Kottum Pullam Palayam	25
Nagadevan Palayam	21
Googalur	18
Kalingium	17
Mevani	16
Nanjai Gobi	13
Allukuli	13
Pallam Palayam	12
Nathi Palayam	12
Palaiya Pariyur Karai	12
Amma Palayam	12
Goundam Palayam	9
Modachur	9
Kollapalur	9
Gobi	8
Pudhu Karai	8
Polava Kali Palayam	7
Pariyur	7
P. Vellavi Palayam	6
P. Mettu Palayam	6
Total	318

Table 3 List of selected sample villages of T. N. palayam block

Name of sample village	Power tiller population
Kaliyan Kadu	22
T. N. Palayam	21
Kondayam Palayam	19
Periya Kodi Veri	13
Kannakkam Palayam	12
Kasi Palayam	11
Arakkan Kottai	7
Permugai	7
Vani Putthur	2
Total	148

Table 4 List of selected sample villages of Nambiyur block

Name of sample village	Power tiller population
Kurumathur	10
Sundakampalayam	9
Pitchampalayam	8
Kadathur	7
Karattu Palayam	6
Irugalur	6
Kadaselli Palayam	5
Total	95

Souce: Dept. of Stastics, Gobi (Table 3, 4)

Mitsubishi (air-cooled) had the most intolerable noise level followed by Shrachi (water-cooled), which could be due to the variation in the muffler systems.

About 49 percent of power tiller operators indicated that the availability of service facilities was beyond 10 km. The power tiller users were solely dependent on the dealers for getting the original spare parts and 80 percent of the respondent said that they were getting the spare parts on time.

Conclusion

Based on the analysis of the results the following conclusions were drawn.

Among the power tiller respondents surveyed, 45.83 percent had education up to middle school level, 35 percent had higher secondary level and more and the remaining were illiterate. Of the power tiller respondents interviewed, 30, 35 and 35 percent, respectively, had purchased the Shrachi (water-cooled), the Mitsubishi (air-cooled) and the Mitsubishi (water-cooled) power tillers, respectively. The nature of the land holding distribution pattern of the power tiller respondents were 30 percent, 26 percent and 44 percent for wet land, garden land, and a mixture of wetland and garden land, respectively. The majority (56 percent) of medium sized farmers (2-4 ha) preferred the purchasing of the power tillers followed by small category farmers. The priorities considered for the purchase of the power tiller, were timeliness of operation (49.30 percent), multipurpose use (48.56 percent), non-availability of labour (45.13 percent) and low purchasing cost (43.15 percent). The average annual working hours of all the makes of the power tiller were in the range of 853 to 888 hours. The major accidents occurred while crossing the bunds with the rotary tiller (91 percent) followed by road transport (84 percent). The cumulative rest time required for the power tiller operator was up to one hour in a day of 8 hours, which was expressed by 67 percent of the respondents.

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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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Ergonomic Evaluation of Cono Weeder for Paddy: K. Kathirvel, Professor, Dept. of Farm Machinery, Agril. Engineering College and Research Institute, TNAU, Coimbatore - 641003, India, **K.P.Vidhu**, PG Student, same, **R. Manian**, Professor, same, T. Senthilkuamr, Research Scholar, same.

The ergonomic evaluation of cono weeder for paddy was investigated to quantify the drudgery involved in the operation (**Fig. 1**). Three subjects were selected for the study based on the age and screened for normal health through medical investigations. The parameters used for the ergonomical evaluation of paddy transplanter include heart rate and oxygen consumption, energy cost of operation, acceptable work load, endurance time, work rest cycle, discomfort ratings and force measurement. Based on the analysis the following inferences are drawn. The mean value of heart rate of the three subjects for cono weeder was 14.03. The heart rate lies in the range of 126 to 156 beats min^{-1} and the corresponding oxygen consumption was 1.251 lit min^{-1}. Based on the mean oxygen consumption, the energy expenditure was computed as 26.11 kJ min^{-1} or 6.22 kcal min^{-1}, the operation was graded as "heavy". The heart rate lies in the range of 126 to 156 beats min^{-1} for about 75 percent of the operating time for cono weeder, necessitating the higher energy demand of the operation. The oxygen uptake in terms of VO_2 max was 63.62 percent. These values were much higher than that of the AWL limits of 35 percent indicating that the cono weeder could not be operated continuously for 8 hours. The work rest cycle for achieving functional effectiveness of the weeder was arrived 30 minutes of work followed by 15 min rest with one operator. Based on the over all discomfort rate (ODR) of 8.03 obtained for weeding with cono weeder and the subjective response, a handle grip with a soft material was suggested to improve the gripping comfort of the operator. The force required for pushing and pulling the cono weeder was 41.25 N and 41.32 N respectively. Standard test code and procedure for the ergonomic evaluation of cono weeder was developed similar to the RNAM and BIS test codes for field evaluation.

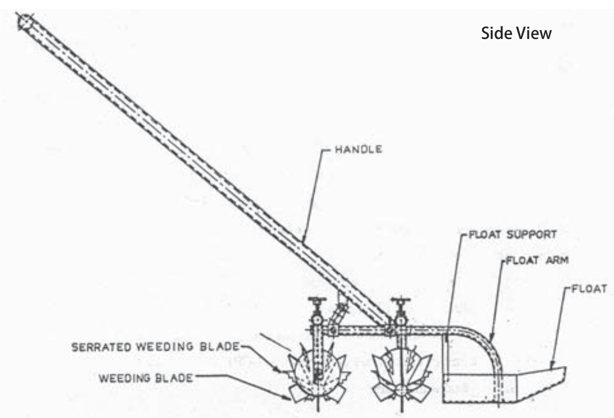

Fig. 1 Cono weeder for pady

290

Development and Testing Of A Variable Width Double Furrow Animal-Drawn Ridger: E.A. Ajav, Dept. of Agril. Engineering, University of Ibadan, Ibadan, Nigeria, **I.S. Atiwaurcha**, same.

A variable width double furrow animal drawn ridger has been developed and tested. The ridger was made from scrap metals and the fabrication was done in a rural blacksmith's workshop. The developed ridger consists mainly of handle, main beam, headwheel assembly and the soil engaging components (share, furrow wing, and ridge wing). The field performance of the ridger under dry and wet conditions were evaluated in terms of draft and field capacity. The performance of a standard ridger was also studied as a basis for comparison. The draft requirements for the dry condition cultivation ranged from 0.5830 kN to 0.5912 kN and that for the wet condition cultivation ranged from 0.6958 kN to 0.7482 kN. The field capacities for both dry and wet condition cultivations ranged from 0.1048 to 0.2095 ha/h. The draft requirements for the developed ridger is 10 % less than that of the locally existing ridger. The developed ridger costs about 50 % less than the existing one. For both dry and wet conditions cultivations, the differences in the average draft were statistically significant at 5 % level of significance. The results also showed that for both dry and wet condition cultivations, there were no significant variations in the field capacities for varied widths/depths at 5 % level of significance.

305

Influence of Process Water Treatments on the Yield and Amylographic Properties of Cassava Starch: O.V. Olomo, Agro-Industrial Development Unit (AIDU), Federal Dept. of Agriculture, P.O. Box 384, Gwagwalada, Abuja, Nigeria, **O.O. Ajibola**, Dept. of Agricultural Engineering, Obafemi Awolowo University (OAU), Ile-Ife, Nigeria.

The poor adaptation of existing cassava processing operations to the infrastructural and economic status of the rural majority (who are the principal producers and primary processors of the roots) has hindered the effective and widespread exploitation of the industrial and other non-food potentials of the crop. Lack of potable water is however one of the uncomfortable realities of rural Nigeria. This paper investigated the effects of different treatments applied to process water from natural sources, on the yield and quality of cassava starch. The quality characteristics investigated were: moisture content, pH, crude fibre content, peak viscosity and pasting temperature. Two main process water treatment modes were used for starch extraction, coded as TRT 1 and TRT 2. The former consisted of filtered stream and well water (FSW and FWW), and their aluminized options, namely, filtered stream water with alum (FSWA) and filtered well water with alum (FWWA). The addition of sulphur, dioxide fumes into all the aforementioned water modes (TRT 2) was also investigated. Analysis of results indicated that starch yields highest when FWW was used for extraction and lowest when FSW was applied. Addition of alum to process water had a significant effect (P>0.05) on the pasting temperatures (PTs) of starches from chips compared to those from flour, with the former having temperatures much higher than the latter. The addition of alum and S02 to process water was conclusively implicated in the significant depression of the peak viscosities (PVs) of the starched extracted.

319

Arsenic Contamination in Ground Water in South-Eastern Bangladesh: **Toufiq Iqbal**, Scientific Officer (Agril. Engg.) and Station in Charge, Rahmatpur Sub Station, Bangladesh Sugarcane Research Institute, Rahmatpur, Barishal, Bangladesh, **Fatima Rukshana**, Scientific Officer, GR Building, River Research Institute, Faridpur-7800, Bangladesh, **S.U.K. Eusufzai**, Head, Agricultural Engineering Division, Bangladesh Sugarcane Research Institute, Ishurdi-6620, Pabna, Bangladesh, **S.M.I. Iqbal Hossain**, Assistant Agricultural Engineer (Grade 1), same.

In recent years, presence of elevated levels of arsenic in groundwater has become a major concern in Bangladesh. Based on the experience of arsenic contamination in the neighboring West Bengal, India, it was initially thought that arsenic contamination would most likely concentrate in the North-Eastern region of Bangladesh. This paper presents the status of arsenic contamination of groundwater in the South-Eastern part of Bangladesh. A total of 305 no. of tube well samples from South-Eastern region were analyzed for arsenic contamination of ground water. It has been found that water in about 29 % exceeds the permissible level (>0.05 mg/l), 29.69 % is within permissible level (0.05 mg/l) and 41.31 % under WHO guideline (0.01 mg/l). The study also revealed that arsenic concentration increases with the increase of depth. Results from this study date from other of the country suggest that arsenic contamination of groundwater in Bangladesh is much more widespread than initially thought. The paper presents results of arsenic contamination in groundwater at the South-Eastern part of Bangladesh and to put some suggestions and recommendations for mitigation of arsenic problem.

405

Efficient Machinery and Equipment for Livestock Farms: **H.C. Joshi**, Principal Scientist, Livestock Production Management Section, Indian Veterinary Research Institute, Izatnagar 243122, India, **Mukesh Singh**, Scientist (Senior Scale), same.

Equipment and machinery have been designed and developed at Indian Veterinary Research Institute, Izatnagar which are useful for livestock farms for different operations like cleaning of animal paddocks, optimum supply of water to animal water troughs and lifting of the injured large recumbent animals for their effective treatment (**Figs. 2** to **4**). An animal lifting system has been developed to lift the recumbent animal effectively with minimal use of man-power. Lifting of animals for their effective treatment is quite essential for an effective treatment. Large ruminants' viz. cattle and buffalo have tendency to remain recumbent following long bone injury, joint affection or neuromuscular disorders. Prolong recumbence may further lead to other complications like bed sores, radial nerve paralysis and tympany. Developed bullock operated dung cleaner is found to be most effective for the routine dung collection operation of the livestock farms. The machine rests over two ADV pneumatic wheels of size 8.00-19 which are attached to standard ADV axle of bullock carts. The machine has collections blade of size 170 x 40 cm which can be lifted or lowered through a foot operated lever mechanism. It can accomplish collection of dung from 74 m^2 area per minute. A low cost float-cock costing approximately Rs. 100/-is sturdy enough for use in dairy farms. It is able to maintain the water level

Fig. 2 Sequence of lifting of injured large animal through developed device

Fig. 3 Low cost float-cock

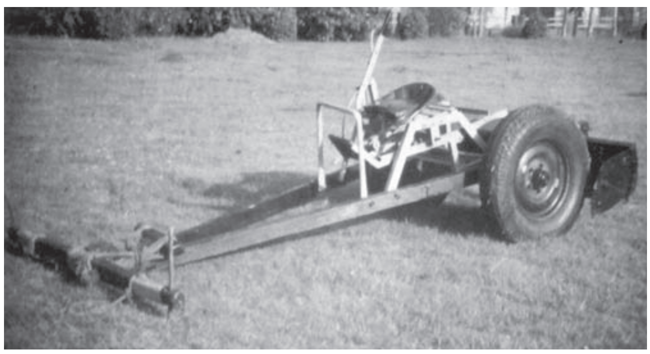

Fig. 4 Dung scraper cum cleaner

in the drinking water troughs meant for the animals kept in loose housing systems. This reduces wastage of water occurring from the unattended water taps to a great extent and improves the hygienic condition of farms.

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Prediction of the Drift Distance of Injected Water Droplets in a Moving Air Stream: Adnan I. Khdair, Associate Professor, Biosystem Engineering Department, Jordan University of Science and Technology (J.U.S.T), Irbid, Jordan, **Lua'y Zeatoun**, Chemical Engineering Department, same

A computer program was used to simulate the effect of several variables on drift distance of injected water droplets in a moving air stream. Variables were initial droplet size of (25 to 500 mm), wind velocity (1.0 to 10.0 m/s), and discharge height (0.25 to 2.0 m). All 75 mm diameter and smaller droplets completely evaporated before depositing 0.5 m below the point of discharge for all simulated conditions. The simulation showed that the drift distance increased by increasing wind velocity and discharge height, but decreased as droplet size increased at a given wind velocity and a discharge height. The simulated drift distance of injected water droplets was fitted to a multiple regression model. The model expresses the drift distance of a droplet as a function of injection height, wind velocity and droplet size. The relative effect of these parameters showed that droplet size has the largest effect on drift distance followed by discharge height and wind velocity, respectively. The model showed also that parameter interaction has significant effect on drift distance at the 95 % confidence level. Droplet size and injection height have a second order significant effect, while wind velocity has a linear effect only.

423

Determination of the Effects of Different Soil Tillage Methods on Some Soil Physico - Mechanic Features in Sugarbeet Cultivation: Koc Mehmet Tugrul, Turkish Sugar Factories Corporation, Sugar Institute, 06790 Etimesgut, 06790 Ankara, Turkey, **Ilknur Dursun**, Faculty of Agriculture, University of Ankara, Dept. of Agricultural Machinery, 6110 Ankara, Turkey.

In this research, it was objected the determination of the effects of different soil tillage methods on some soil physico - mechanic features in sugarbeet cultivation. The methods that were estimated in this research are traditional soil tillage methods and five different methods which were considered to be feasible in Turkey. The soil physico - mechanic features, which were observed in the study, are soil moisture content, dry bulk density, soil aggregate size distribution and penetration resistance. In conclusion it was determined the best results in S1 and S2 in terms of the soil physico - mechanic features.

445

Storage of Groundnut Seeds Under Different Conditions: K. Rayaguru, Assistant Research Engineer, AICRP on Post Harvest Technology, CAET, OUAT, Bhubaneswar, Orissa, India, **K. Khan**, Research Engineer, same.

Among the different oilseeds grown in Orissa groundnut is considered as a major potential source because of its yield economics. But the unavailability of seeds stands as a major constraint for extensive coverage. This problem can be solved only if groundnut seeds, which are harvested towards end of May, are preserved, so that seeds can be made available to the farmers at the right time during October sowing without losing the available residual moisture. This becomes significant during the period from June to November due to prevailing high temperature and high relative humidity. Storage experiments were carried out using different farm level structures like bamboo doli, metal bin and insulated metal bin. Groundnut seeds were also stored under dehumidified refrigerated storage conditions of temperature 15 ± 1 ºC and relative humidity 60 ± 2 % The sun dried groundnut seeds (AK-12-24) procured from farmers of Orissa were used for the experiments. Before storing the seeds in different storage structures the samples were drawn and analysed for the initial seed qualities. During storage of seeds the prevailing atmospheric temperature and relative humidity were recorded regularly. The performance of each storage system was evaluated at 20 days interval through the standard tests for moisture content, germination percentage, viability percentage, vigour number and seed health. Analysis of observations on seeds stored under different conditions for a period of 18 weeks more or less coinciding with the critical period for the seed life concludes the following findings. Bamboo doli is the structure most prone to changes due to the outside climatic conditions and therefore the seed quality declined much earlier than that of metal bins. However the insulated metal bin gave slightly better performance than that of the non-insulated metal bin. In this respect dehumidified refrigerated storage maintained all the seed qualities to a large extent at the end of 18 weeks of storage period.

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Application of Enamel Coating in Draught Reduction of a Mouldboard Plough: I.A. Loukanov, PhD, MSc, Senior Lecturer, Department of Mechanical Engineering, University of Botswana, P/Bag UB0061, Gaborone, Botswana, **J. Uziak**, PhD, MSc, Associate Professor, same.

This paper studies the effect of an enamel coating on the draught performance of an animal-drawn mouldboard plough (**Fig. 5**). A single furrow mouldboard plough-Maun Series, and the same type enamel-coated plough, both ox-drawn, are compared under similar working conditions such as soil moisture content, depth and width of cut, and approximately constant speed of ploughing. The enamel coating has reduced both the actual and specific draught. The percentage reduction of actual draught for enamel-coated plough as compared to uncoated one varied from 12.7 % at 25 % d.b. soil moisture content to 18.1 % at 32 % d.b. soil moisture content, whereas the percentage reduction of the specific draught varied from 25.7 % at 25 % d.b. soil moisture content to 20.3 % at 32 % d.b. soil moisture content.

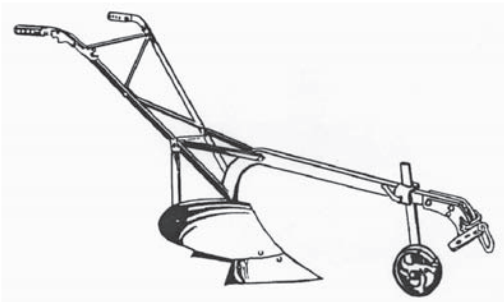

Fig. 5 The maun plough

452

Thermal Control of Stored Grains Insects by Utilizing Solar Energy: **Ali M.S. Al-Amri**, Dept. of Agricultural Engineering, College of Agricultural and Food Sciences, King Faisal University, P.O. Box 4421, Al-Ahsa 31982, Saudi Arabia, **Sirelkhatim K. Abbouda**, same.

Storage insect-pests are the major cause of damage and losses in food grain. For prevention of damage and losses by insects infestation, all insects present in the stored product must be eliminated at any stage of their development. Preservation methods which applied to food products for insect pests control, as chemical method, resulted in several problems and hazard for consumers. Heat treatment is one of the safe alternative measures for storage insects control but it is costy and requires special facilities for application. Therefore, the aim of this study is to utilize solar radiation as source of heat for thermal control of storage insects, in an attempt to find out a safer effective control measure at minimal cost. To study the effect of material, black paint, and transparent cover on heat observation, four groups of containers were from different materials (plastic, polythene, metal and jute). Two containers from each group (out of three) were painted black and one from these two black containers was covered with transparent polythene. All containers were filled with equal amounts of sorghum grains and kept out door for exposure to direct sun radiation. Temperature measurements were taken at two hours time interval from 8:00 A.M. to 1:00 P.M. for the first period and from 1:00 P.M. to 5:00 P.M. for the second period. Five structures of different geometrical shapes made of black galvanized metal were used to study the effect of geometrical shape on heat absorption. All containers (pyramid, cylindrical, triangular, rectangular and cubic) were filled with sorghum grain and temperature measurements were taken as mentioned above. Highest maximum temperature were observed in black plastic container (64.7 ºC), black polythene container (64.2 ºC) and black metal container (58.3 ºC) when covered with transparent polythene. These temperature were found to be greater than the lethal temperature (45 º C) for all developing stages of storage insects. The structures with inclined surface like pyramid and triangular recorded the highest maximum temperatures compared to vertical structures. Generally, it could be concluded that solar energy could be utilized for control of storage insects with simple treatment of the containers tested in this study under Al-Ahsa conditions throughout the year.

454

Experimental Research on Physical Properties of Coated Rice Seeds: **Yang Ling**, Lecture, Engin Tech College, SW Agric. Univ., Chongqing 400716, China, **Yang Mingjin**, Lecture, same, **Li Qingdong**, Professor, same, **He Peixiang**, Associate Professor, same, **Chen Zhonghui**, Professor, same.

Some physical properties, bulk density, particle density, restitution coefficient and drag coefficient, were experimental researched for the coasted seeds of three hybrids widely cultivated in Southwest of China. By means of orthogonal experiment design and analysis of variance (Anova), major factors and their significant levels affecting these properties were determined. Practical date were obtained as well.

455

Mathematical Analysis for Predicting the Suitable Amplitude of Shaking Unit in Mechanical Harvesting of Fruits: **Mohamed I. Ghonimy**, Associate Professor, Agricultural Engineering Department, Faculty of Agriculture, Cairo University, Egypt.

The mathematical analysis provided an equation for predicting the suitable-shaking amplitude of limb tree shaker. This mathematical equation correlated the pulling force to fruit mass ratio, stem length, shaking frequency and damping ratio. The mathematical equation was checked under two circus varieties; Valencia and Grapefruit. The practical study showed that, the mathematical derived equation could be used with enough confidence in predicting the shaking amplitude of shaking unit in mechanical harvesting of citrus fruits. The optimum fruit removal percentage without limb damage was 97 % and 97.5 % for Valencia and Grapefruit varieties respectively. These values were realized at the following parameters: 0.4-1.2 cm amplitude; 7-6 Hz shaking frequency.

470

Development and Evaluation of Manual Weeder: **Rajvir Yadav**, Associate Professor, Department of Farm Machinery and Power, College of Agril. Engg. and tech., JAU, Junagadh 362001, India, **Sahastrarashmi Pund**, Ex Research Associate, CAET, GAU, Junagadh, India.

To increase the productivity per unit area of small land holding of farmers and considering their economic condition, it is quite necessary to have suitable agricultural implements by which farmers can use them and also allow custom hiring (**Fig. 6**). Weeding is an important agricultural operation affecting crop yield upto 30 to 60 percent. With regard this, a manually operated weeder was developed and tested considering various parameters such as speed of travel, weeding efficiency, time of operation, field capacity, crop height, plant population and horse power requirement. The ground wheel of weeder (390 mm) was fabricated from mild steel flat of 52 x 3 mm. The weeding blades were made from steel flat, which is strong enough to sustain the prevailing forces as well as to carry, the load of the implement. V-shape support was fabricated from mild steel and was directly welded to the handle to join the ground wheel with the main frame. The arrangement was also made to adjust the height and angle of the handle as per the need of the operator. The weeding efficiency of the developed weeder was satisfactory and also easy to operate. The developed could work upto 3.00 cm depth with field efficiency of 0.048 ha/hr and higher weeding efficiency was obtained upto 92.5 %. The rest pause of 14 min was required by the subjects during the heavy work to come to normal position. The peak heart rate was found to range from 142 to 150 beats per min. The overall performance of the weeder was promising.

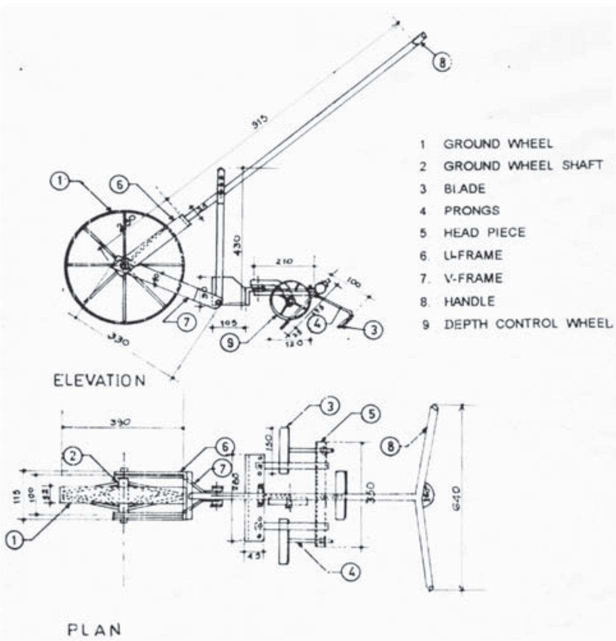

Fig. 6 Groundnyt weeder

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Kinematic Analysis of Manually Operated Dung Collector: **Preetinder Kaur**, Asstt. Research Engineer, Dept. of Processing and Agricultural Structures, PAU, Ludhiana, Punjab, India, **P.S. Grewal**, Associate Professor, same, **Beeba Sahib Kaur**, Project Student, same.

Kinematic analysis was carried out to improve the design of an existing manually operated cattle dung collector. An improved wheel-mounted, manually pushed dung collector was developed in the Department of Processing and Agricultural Structures, Punjab Agricultural University, Ludhiana. It comprised a dung-collecting bucket, pivoted on a frame. Tilting the bucket with the help of a foot-operated lever emptied it. From the experience of the dairy farm workers, existing design of the dung collector required certain changes for convenience in operation and to reduce the labour requirements. Accordingly, the height of the foot lever was reduced from 53.34 cm to 30.48 cm. The width of the bucket was reduced to two-third, thereby increasing convenience. The modified dung collector took 47.5 % less time than the existing one for dung collection. The paper contains the details of the kinematic analysis and synthesis processes that were employed to incorporate the required modifications in the eqiopment. ■■

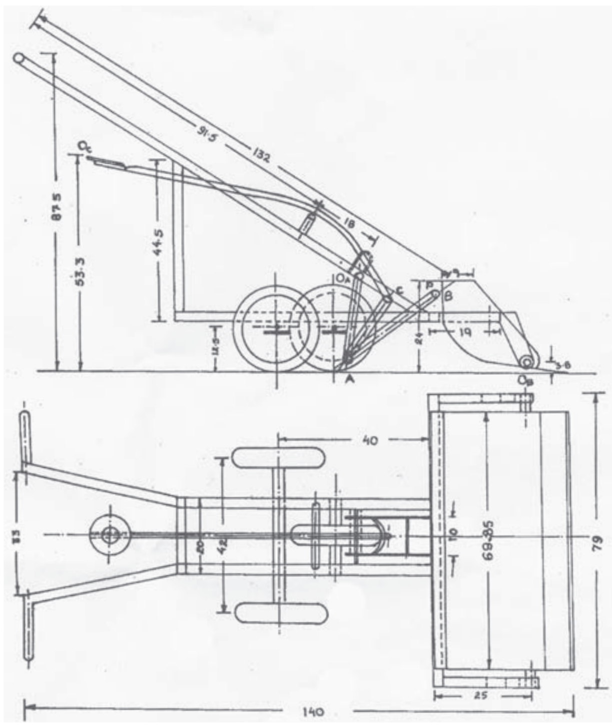

Fig. 7 Side evaluation and plan of modified dung collecter

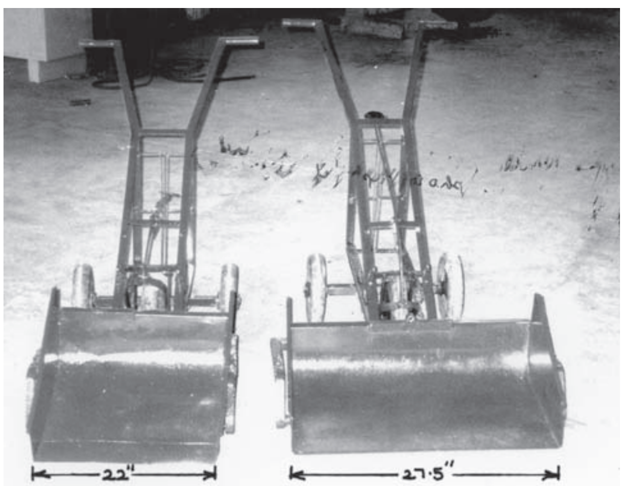

Fig. 8 Illustration showing the difference in the size of the backet

Round Table on Rural Areas Development in SEE

Agricultural Engineering and its Role in Development of Rural Areas

Organization of Agricultural Engineering of Southeastern Europe - AESEE, a member of CIGR since 2005, has recognized importance of rural development in the region and world wide. The round table Agricultural Engineering and its Role in Development of Rural Areas has been initiated by AESEE and organized by Turkish Chamber of Agricultural Engineers, Izmir Branch, on 25th to 27th of September in Izmir and village Sirince. Ten participants from five countries, fully supported by the presence of CIGR President Prof. Dr. Luis Santos Pereira have discussed a very actual problem of rural area retrogression.

At the beginning, all participants agreed that most of rural areas, world wide, are endangered from economic, environmental, societal and demographic point of view. It is typical that poverty and lack of perspective in rural areas generate migration and boom of poor suburban settlements with lots of problems for all inhabitants. Consequently, many problems occur in the cities and rural areas. The extrapolation of present trend shows vision of enormous environmental and societal disharmony.

During a very open discussion, many problems of rural areas and its importance for whole society have been mentioned. Rural tourism is perceived as a good chance, but nevertheless, excessive development could harm both local culture and environment. Large scale industrialization of rural areas has, in some examples, proved to be the wrong remedy. Local festivals based on cultural tradition, traditional food, handicraft etc. support self-awareness of rural area inhabitants. The problem of inadequate infrastructure was addressed with full understanding. Due to a much lower population density, compared with cities, solving this problem is much more expensive in rural areas. Contemporary ICT tools have been identified as good aids in overcoming this problem, e.g. E-commerce and general communication improvement. Brave ideas were to introduce new contents in villages - DJ courses, summer schools teaching attractive disciplines, gerontology centers - to name but a few. This could boost interest for rural areas, especially within young people and create employment opportunities for educated qualified persons.

Difficult situation in the sector of agriculture, world wide, also influences economy in rural areas. Agricultural production is multi-functional, having many non-economic effects. This should also be acknowledged when making local, regional or global policies. Disturbance of agricultural production can have economical, societal and environmental consequences.

How could agricultural engineering contribute? It was concluded that most institutions in this field serve less than 10 % of population in rural areas. All efforts are concentrated towards increase of productivity on best organized large farms which are most profitable. Who will help the rest of 90 % of farmers? How to help them? Some of the ideas were: to restructure extension service, to develop inexpensive agro products and agro food safety and quality technique, to develop procedures and equipment for post-harvesting processing on farms, up to the level of producing the super market shelf-ready commodities. This can be accompanied by the local production of machinery in small workshops. Another issue can be the use of renewable energies for own needs and for the market. All this can be considerable support for better living conditions in rural areas.

In the time of globalization, the awareness of cultural uniformity is ever more pronounced. In that respect, rural areas could be our last chance to rescue cultural diversity as the heritage of mankind and civilization.

Main round table's impression was that a complete and precise inventory of rural areas' problems is still missing, especially in the region of Southeastern Europe. In order to define those problems, set priorities and programs, a multidisciplinary research shall be required.

Participants of the Round Table from the AESEE member countries and the President of CIGR concluded that:

1. The problems of rural areas in the region of Southeastern Europe and also worldwide are recognized. The most significant problems in the region are;
   i. poverty,
   ii. migration to the cities,
   iii. lack of appropriate infrastructure,
   iv. size and fragmentation of farms.
2. The society and agricultural engineering profession should be aware of these problems of welfare of rural area inhabitants and provide solutions in order to achieve comparable living conditions with those in cities.
3. Agricultural engineers, besides their common professional activities, should also create the awareness of the rural area problems in the society through educational process and media.
4. Multi functionality and non-economic values of agriculture should be recognized by the society, i.e. preventing desertification, preserving the environment and landscape.
5. Continuation of rural life enables preservation of cultural heritage and contributes to cultural diversity.
6. A working group on this issue should be setup in the frame of CIGR.
7. Agricultural engineering must support development of on-farm processing up to getting shelf-ready products especially of traditionally home made foods. Assurance and control of safety and quality of this production is a special challenge for agricultural engineering.
8. Extension services of any model of organization should be supported in any means, but reinforced in the quality, being able to help solving also other herewith identified needs or rural area.
9. Indigenous knowledge should also be respected and included in tools aimed in participatory rural development.
10. A multi-disciplinary regional project is needed to state problems of rural areas more precisely, to define possible solutions and needed tools. Such a project will include diverse expertise from the scientific fields of sociology, demography, economy, technology, etc. And will be drafted in first half of 2006.
11. Implementation of renewable energies can be a good tool for develop-

From left to right: Agricultural Engineers Paul L. McConnie, Megh R
Francisco Monroig, Eric Harmsen, Carmelo A. Gonzalez and

ment of rural areas through which local materials and human resources can be used. Prof. Dr. Milan Martinov is given the responsibility searching for funds and drawing a concept of a regional project on this topic.

Presidency and Management Committee - the Club of Bologna

Conclusions and Recommendations

1. Foreword

The Session of the Club of Bologna began with a very important matter, the future of agricultural engineering. In the past, in the developed countries, and now in the developing world, agricultural mechanisation and engineering have been the main responsible for the transformation of agriculture.

A few months ago a bomb exploded in the agricultural engineering world: FAO is closing the agricultural engineering sector, as it may be seen looking the report "**2006-07 - Supplement to the Director-general's Programme of Work and Budget (Reform Proposals)**", by FAO, published in August 2005 (web ftp://ftp.fao.org/docrep/fao/meeting/009/j5800e/j5800e_sup1.pdf):

The Club of Bologna unanimously approved at the end of the Session on 13th Nov. 2005 the FAO Recommendation, which is reported at point 3.

2. Conclusions and Recommendations

63 experts from **25 countries in addition to different international organisations** took part in the 16th Club of Bologna meeting, held on 12 and 13 November 2005 within the XXXVI EIMA Show, under the aegis of **CIGR** and with the sponsorship of UNACOMA.

There were two topics under discussion, of which the first was "**Alternative Fuels for Agricultural Machinery Utilisation**"with keynote contributions by three speakers: Dr. Gustavo Best, FAO Senior Energy Coordinator, with a paper on "Alternative energy crops for agricultural machinery biofuels (focus on biodiesels)"; Prof. Dr. Ing. Giovanni Riva, Università Politecnica delle Marche, who spoke on "Utilisation of biofuels (especially vegetable oils) in the farm"; Dr. Hartmut Heinrich, Director of Research on Fuels and Oils, Volkswagen AG, with a contribution on "Utilisation of biofuels (especially biodiesels) on internal combustion engines".

The second topic was "**New Raw Material for Agricultural Machinery Manufacturing**", with two keynote papers by Dr. Robert Adams, representing the CNH tractor and equipment manufacturer, "Reasons and impact of steel price increase on agricultural machinery industry" and by Dr.-Ing. Klaus Martensen, Maschinenfabriken Bernhard Krone KG, "Progress in typical materials for agricultural machinery".

Conclusions

Topic 1. The first paper (**Alternative energy crops for agricultural machinery biofuels - focus on biodiesel.**) was presented by Dr. Gustavo Best, FAO Senior Energy Coordinator. There is a large variety of bioenergy sources, each one with social and scientific implications on rural poverty, high-tech industry, agronomy, new crop development and selection, land tenure issues, biodiversity impacts, rural employment, etc.

Biodiesel is a clean burning alternative fuel, produced from biological oils. Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a biodiesel blend. It is biodegradable, non-toxic and essentially free of sulphur and aromatics.

Biodiesel main origin are the following crops: soybean, rapeseed, sunflower, palmoil, linseed, canola, etc. The US National Biodiesel Board concluded that the energy balance for biodiesel may be from 1.44 (not including a credit for byproducts) up to 3.2. Advantages of biodiesel are: it is environmentally superior to other fuels (50 % less CO; 80 % less CO_2; etc.); actually cleans engines; can be grown in arid, marginal, degraded lands; less toxic than table salt; byproducts may be used in agro- and livestock industry.

In 2004 the main biodiesel producers had been Germany, USA, France and Italy. Production is increasing by 20-25 % per year and has reached around 2.5 million t. The future vision is positive and the international bioenergy programme is pointing to promote and monitor the sustainable use of modern systems for a sustainable development, energy security and climate change mitigation.

The second paper (**Utilisation of biofuels (especially vegetable oils) in the farm**) was presented by Prof. Ing. Giovanni Riva from the Università Politecnica delle Marche (Italy). The utilisation of biofuels in the farm is different following the increase in the cost of fossil fuels in comparison with the perspectives for agriculture. There are three different groups of countries:

- countries with industrial agriculture (e.g. in Argentina and Brazil in South America);
- western industrial countries (e.g. the European Union EU);
- less developed countries (many countries around the world).

In the first group of countries the cost of agricultural products is lower and competitive and big plants for the transformation of the raw material could be feasible. Very often the possibility to convert the raw material in food and/or in biofuels may be a way to optimise the income of agriculture.

On the contrary in the western industrial countries the value of commodities is decreasing, with a consequent low profitability. Incentives are given for the RES (Renewable Energy Systems) development, especially for the "green electricity" and very often the idea to produce crops for energy production is studied with a great interest. In the EU the renewable energy consumption on the total gross energy is at present about 4 % and it is planned its increase to 5.8 % in 2020 and to 6.5 ten years later.

At last in the less developed countries the following points must be taken into account: economy is stagnating and subsidies are given in fossil fuels; energy needs are often solved by diesel generators; rural development is problematic; cost of energy efficiency (EE) for rural communities is usually very high and this justifies labour and investigation for EE production.

The following advantages must be taken into consideration: oleaginous crops are possible with all climatic conditions; the oil is extractable from the seeds with very simple machines; the byproduct from the pressing operation is a cake and it is often interesting to use it as a fertilizer or as a feedstock; diesel generators sets may be directly used with vegetable oils.

As a conclusion the use of raw vegetable oils seems an interesting option, when the quality of these oils is controlled. It is a must to prepare standard lines for the use of pure vegetable oils for diesel engines.

The third paper (**Utilisation of biofuels (especially biodiesels) on internal**

combustion engines) was presented by Dr. Hartmut Heinrich, Director of Research on Fuels and Oils, Volkswagen AG. The world energy demand is rapidly increasing and non-conventional fuels (coal, CH_4/H_2, gas, new renewables) will fill the future energy gap. The demand on future fuels must fulfil a safe supply, an easy handling and storage, a high energy density, an economic competitiveness in addition to the consideration of environment and climate protection.

Future fuels should be such to be blended into existing fuels and be diversified on the primary energy side. The scenario of the fuel evolution is from diesel to synthetic fuels (based on natural gas and coal), to sun-fuels (based on renewables) and to hydrogen (also based on renewables). The EU scenario is foreseeing by 2020 8 % of biofuels, 10 % of natural gas and 5 % of hydrogen, with a total of about 23 %.

Due to its properties (material incompatibilities, non fulfilment of stringent exhaust gas legislation, non compatibility with diesel particulate filters and with preheaters) a pure biodiesel cannot be used and it is rejected by the automotive industry; but it can be added to crude oil in the refinery.

As a result in the EU 25 (the European Union with the 10 new members, admitted in 2004) it is possible to blend at the moment up to 5 % biodiesel, but the automotive industry is open for a 10% blending in a few years. In the EU 25 the diesel fuel demand in 2005 is 169 Mt, supposed to increase to 197 Mt in 2010, of which at present biodiesel is 13 Mt and will reach 23 Mt in 2010.

Topic 2. The first paper (**Reasons and impact of steel price increase on agricultural machinery industry**) was presented by Dr. Robert Adams, representing the CNH tractor and equipment manufacturer. Steel has been of paramount importance and is heavily used in the manufacturing of machinery and equipment. Its supply and price were not a problem up to a couple of years ago. Due to a strong steel consumption in China, India and other Asian areas, prices recently grew up and available stocks went down. As an example Chinese economy's share of global market doubled to 4 % in the last decade, but she is consuming 27 % of world steel products, with a demand increasing by more than 20 % per year.

For tractors and combines, CNH relies on steel products as the principle source of components. For a tractor, ferrous metal products represent 30% of costs; for combines this dependence goes up to a 44 %. To overcome this point, it has been decided to implement a global commodity strategy focused on quality, technology, delivery and total costs, through a strategic approach to: standardisation, technical saving, global sourcing, alternative technologies.

A disciplined process has been carried out to identify cost reductions from material specifications through to manufacturing processes, with actions that could result from a change of a component or component system, including: delete component functionalities; change material; standardise/communisation; reduce number of manufacturing processes; increase tolerances; reduce weight; simplify/change packaging; benchmark against competitor solution.

The second paper (**Progress in typical materials for agricultural machinery**) was presented by Dr.-Ing. Klaus Martensen, Maschinenfabriken Bernhard Krone KG. The recent most important milestones in the agricultural machinery manufacturing can be listed as follows: combination of several process steps in one machine; oil hydraulic drives and controls; electronic controls; extreme increase in the performance of individual machines.

Not long ago, a typical agricultural machine consisted almost exclusively of "iron and steel". This has changed and the main reasons are: higher load on the component due to increased performances; imperative light-weight design on account of legal regulations and avoidance of soil compaction; increase of the resistance to wear due to higher loads on components; increased demands on lifetime of modern machinery; increased demands on design and ergonomics.

Let us consider the material groups: structural steels; alloyed steels; cast materials; light alloys; wearing materials; synthetic materials. Machinery size is increasing, but legal requirements limit the total weight and/or the weight per axle. As a consequence fine-grained structural steels, high-quality alloyed steels and cast iron and steel are generally used. For machinery parts subject to wear, blades and other similar components are coated with hard metal parts.

Light aluminium alloys are used to reduce weight, especially when a front or rear attachment requires to minimise the weight transfer from one axle to the other. Also gear housing of the various drives contribute to this end.

Synthetic materials are employed in versatile forms. Today, aesthetically shaped panelling dominates the market: glass-fibre reinforced plastic; thermoplastic materials; rotational moulding or rotational sintering process polyethylene parts.

In the future other new materials will be used: metal matrix composite steel and ceramic materials, for wearing materials; piezoelectric materials, with the size increasing when an electric current passes through; twinned martensite, where a high load deformed part may return to the original shape by a simple heating.

Recommendations

Topic 1

- **Having recognised** that China, India and other developing countries economic uprising had a major influence on the fuel market in the past few years and that oil prices are forcing to develop new energy sources;

- **Having noted** that biofuels (biodiesel and bioethanol) are a necessary component of future energy supplies and that they attract a growing interest by politicians, the public, the farmers and that the best option is the conversion of biomass into liquid fuels;

- **Having recognised** that in the future energy scenario the contributions from agriculture are a must and that following the Kyoto protocol for a clean development, it is necessary to develop a conservation agriculture with alternative crops for bioenergy, considering the emission control;

- **Having noted** that the relationship between the oil and the energy crops prices and the tax situation in both products in each country is very important and that legislation is influencing sometimes in a positive and sometimes in a negative way the research and studies on various biofuels and their local production and diffusion and that subsidies are not normally accepted by WTO, although exceptions already exist;

- **Having noted** that manufacturers are normally conservative and not in favour of alternative fuels and that engine manufacturer design will be driven by the large scale producers, i.e. the automotive industry;

- **Having recognised** that bioethanol and biodiesel are products actually applied in some remarkable quantity and that a high level of efficient transformation from sugar cane to ethanol has already been achieved in Brasil and that the German "100 tractor programme", supported by the government, demonstrated that pure rape seed oil is not able to be used economically for mobile machinery right now, as about 35% of the machines had severe break downs;
- **Having recognised** that EU is supporting the use of alternative fuels even if pure biodiesel seems to be not well suited for modern diesel engines for passenger cars with particle filters, while for trucks and agricultural machines the situation is different and that a general agreement on diesel engines fuels can be used in a mixture of 5 % biodiesel and 95 % conventional diesel, with increasing percentage of biodiesel for the future;

The members of the Club of Bologna:

- **Recommend** that to find the most effective system of transforming biomasses into energy and biofuels seems to be the most feasible and sustainable alternative to provide a clean, renewable and environmentally friendly energy source, not only for agricultural machinery but also for automotive and transport means;
- **Underline** that the processing of alternative fuels (from plant to tank) must be improved and that BTL (biomass to liquid) fuels shall be further developed in the (near) future;
- **Acknowledge** that the approach for developing bioenergy utilisation should be based on local social-economic conditions and that even if in EU the biodiesel is now to be blended in a 5 % percentage, in developing countries there will be more expansion of bio-based fuels, as it is possible to implement easier transformation process and input preservation;
- **Underline** that the production of biofuels need a careful planning of the agricultural activity at regional, national and international (in the EU) level and of the areas where biomasses are produced in order to optimise (reduce) the transportation costs, with the precondition of a low energy input for cultivation;
- **Confirm** that the cultivation and transformation of biomass are essential to the development of agriculture in a future; in addition in a lot of countries marginal lands shall be used to prevent an impact to food security and conserve the limited farmland for grain production;
- **Reassert** that on the contrary a broad cultivation of the alternative energy crops according to the climatic and soil conditions are a suitable solution for the cultivation of crops for non food production purposes in the countries with food over-production as well as an important help in the energy supply and protection of environment;
- **Underline** that the relationship between the prices of natural oil and biocrops and tax situation determinate the possibility of developing these technologies in each country and that it is further necessary to promote bio-energy with research, development, dissemination of knowledge and subsidised and non-taxed applications;
- **Confirm** that future research and development related to renewable fuel and energy is very important and acknowledge that bioenergy is coupled with a number of problems of "waste products". These do not get enough consideration in the energy balance. Agricultural engineers must take into consideration both the problem of waste management and environment impact;
- **Remind** the conclusion of the "100 tractor programme" in Germany, that has to be studied and be taken into account to avoid the possibility for farmers to damage their tractors by using inappropriate fuels;
- **Underline** that with the worldwide increase in biofuels, it is important that FAO takes a leading role in their promotion, to coordinate research and convene international meetings on the regulations and trade aspects of biofuels in the global markets;
- **Underline** that agricultural engineers must collaborate with the big engine manufacturers, but with the important need to understand and develop processing of biofuels crops in order to ensure as much added value as possible;
- **Reassert** that in spite of the difficulties of using pure biodiesel, a scenario may be successfully developed to increase the percentage of biodiesel in the marketed diesel fuels, in such a manner that a considerable market share of biodiesel versus the overall diesel fuel consumption is achieved;
- **Recommend** that quality of biofuels should be standardised internationally according to the needs of efficiency of the combustion and with respect to the reliability and durability of the internal combustion engines;
- **Acknowledge** that the chances of using pure plant oils - especially in developing countries with a deficit energy supply - are rather seen for stationary power plants and that stationary plants can better handle not only pure plant oils but also pure biodiesel than mobile machines.

Topic 2

- **Having noted** the increasing cost of raw materials and especially of steel;
- **Having recognised** that it is not easy to forecast the future trend of steel prices;
- **Having noted** that China development had a major influence on the steel market in the past few years, including the availability and price of steel;
- **Having noted** that the cost of high tech materials such as fine-graded steels increases more than proportionally with their performance and that for the manufacturing of agricultural machinery cost, weight and environment view points have to be considered;
- **Having recognised** that for agricultural machinery there are few alternatives to steel as a material that provides strength and that the economic development and the requirements for weight reduction and operational life of equipment make that a lot of attention goes to rational selection of materials for equipment;
- **Having noted** that high tech materials are today a standard in highly developed countries for agricultural machinery manufacturing and that the utilisation of new materials will increase in the future, but the most important factor in addition to technical consideration is their price, which will determine the effective use of these new materials;
- **Having recognised** that the quality and reliability of materials are important and that manufacturers are prepared to transfer the cost of good quality materials on the customers;

The members of the Club of Bologna:

- **Reassert** the necessity to increase the search for new materials, including new technologies to mould and/or to cast and/or to shape them, and **recommend** optimisation procedures for design that include the new materials, to make it possible for manufacturers to introduce these materials in a cost-effective way;

- **Acknowledge** that the general trend of material cost is favouring interesting chances for a general use of high tech materials;

- **Underline** that light weight materials, manufactured with light metal alloys, should be applied to agricultural machinery when appropriate, especially to reduce the weight of equipment to avoid soil compaction;

- **Underline** that the Chinese boom will probably return to a balance with slightly reduced steel prices, so that price contracts on steels could become again possible and the importance of spot markets will decrease;

- **Recommend** that small and medium sized manufacturers should be educated on materials trends and alternative materials;

- **Confirm** that to improve and develop new and better alternative materials, a condition is to encourage, to invest and to carry out research and development both at university and in industry, to also reduce dependency on steel and **suggest** to use a more intensively optimisation methodology in design of farm machinery supported by shape and parametric analysis;

- **Reassert** that consideration should be pointed to reliability, serviceability, time required for repair and maintenance, etc., to achieve an optimum design;

- **Underline** that the question of material recycling and eco-technologies should be faced and studied, as biodegradable materials are not at present a practical alternative;

- **Recommend** a bigger use of biomaterials and renewable materials in agricultural machinery and other products manufacturing, to improve efficiency, reduce costs and give the possibility to recycle them;

- **Recommend** that the research institutions and the industry should be encouraged to work together in order to develop biological materials, to replace the metal and plastic materials used in the manufacturing of agricultural machinery and equipment.

3. FAO Recommendation

"The Club of Bologna (www.clubofbologna.org) is an independent, non profit association with the aim to promote, study and define strategies for the development of agricultural mechanisation worldwide, taking into consideration technical, economic and social advances and changes in agriculture on an international level.

The Club of Bologna, founded in 1989, has about 120 members coming from almost 50 countries of all five the continents. On 12th and 13th November 2005 it has hold its 16th Meeting of the Full Members with the participation of more than 60 people.

Having known that the FAO is discussing (see the Report "2000-07 Supplement to the Director-General's Programme of Work and Budget (Reform Proposals)":

- point 51, page 12 "Several areas would be significantly reduced....These include:
  - ....
  - agricultural engineering and agricultural services information, which would only be covered through thematic networks with other institutions"
- point 200, page 52 "Support activities to farm power and mechanisation or agricultural engineering would be pursued essentially within the context of knowledge exchange and outreach programmes directly in countries:",

the Club of Bologna reminds that the main measures for increasing crop yields in developing countries are:

- seeding technique, through modern tillage and drilling, which could possibly increase yield by 15 -35 %;
- seed quality (selected seeds) by 30-150 %;
- chemical products (fertilisers, spraying products) by 50-500 %;
- harvest (modern harvesting techniques) by 20-35 %;
- water (irrigation) by 50-500 %;
- crops/year (with machinery for peak periods) by 25-100 %;
- storing (modern drying and storing) by 10-50 %;
- transport (use of adequate transport means) by 10-50 %.

Of these eight listed techniques, five depend on machinery use. In addition an FAO report, based on agricultural statistics worldwide, stated that at world level the agricultural production highly depends from installed farm power, especially when farm power is limited, as it happens in developing countries.

Having considered all the listed points, the Club of Bologna invites the FAO to reconsider its position regarding agricultural engineering and mechanisation, as these sectors are essential for the development of agriculture in the developing countries and for the general welfare of their inhabitants."

Carl-Albrecht Bartmer Elected as New DLG-President

Professor Dr. Achim Stiebing New Vice President - Helmut Ehlen Confirmed as Vice President

(DLG). The German Agricultural Society (DLG/Deutsche Landwirtschafts-Gesellschaft) has elected its new president - Carl-Albrecht Bartmer of L_bnitz a.d. Bode (Saxony-Anhalt), Germany. The Executive Committee elected Bartmer in Berlin on 11 January at its winter conference last week, which takes place once a year. Bartmer succeeds Baron Philip von dem Bussche, who stood down following nine year's of service. Baron Philip von dem Bussche will continue to contribute with his wide-ranging expertise and experience in his capacity as Member of the Board. The Supervisory Board also confirmed Helmut Ehlen, a farmer of Ahrensmoor, as one of two honorary vice presidents for three further year's of service. Professor Dr. Achim Stiebing, chairman of the German Agricultural Society's DLG-Test Centre for Food was elected as vice president. He succeeds Professor Dr. Friedrich Kuhlmann, University of Giessen, Germany, who has decided to retire on age grounds.

Carl-Albrecht Bartmer, 44, owns and manages an agricultural business of 1.000 hectar. He is the youngest president in the history of the German Agricultural Society and belongs to a breed of young entrepreneurs who have shown commitment to the society in recent years. During the last 15 years, Bartmer has shown extraordinary pioneering spirit in turning around his family business into a successful enterprise, which dates back to 1735. Through his visionary and contagious entrepreneurial prowess and a cost-conscious approach, he manages to combine key company functions. The dedicated marathon runner und horse rider is characterised through his openness, perseverance and consistency. Bartmer previously held the position as Chairman of the DLG-competence center for agriculture and food and as Chairman of the DLG Committee for farm management. He is Member of the Executive Committee and has been a Member of the Board of Management for the last six years. Bartmer comes from a family in which entrepreneurial spirit and active collaboration with the German Agricultural Society are traditions. Following A-levels and agricultural business apprenticeship as well as academic agricultural studies in Goettingen, Germany, he was offered the opportunity to manage a seed-growing business in Schleswig-Holstein, North Germany. Further education in business management together with an international outlook are for Bartmer corner stones in today's business environment.

The international exchange of experience within and across sectors is also of prime importance for him. For several years, Bartmer has been representing the DLG society at a European level.

With the election of Professor Dr. Achim Stiebling, for the first time in the society's 120 year history there is a vice president for the food industry. Professor Stiebing is a recognised meat and quality specialist from the University of Applied Science of Lippe and Hoexter in Lemgo. For 30 years, he has been contributing with his expert knowledge to the DLG-society. In 1991 he took over the scientific leadership of raw sausage testing. In 1997, he became member of the committee for agriculture and deputy chairman for the department of food as it was called then. He has also served as chairman of the newly-formed DLG-Test center for food since 2005. Through his research experience as well as his understanding of the strategic direction, he has become an important advisor in the area of quality in the food industry. Following his apprenticeship in the meat sector, Professor Stiebing studied food and bio technology at the University of Applied Acience in Belin as well as at the Technical University also in Berlin. Following that, he held a research position at the Federal Research Center for Nutrition and Food in Kulmbach. In 1991 he was nominated Professer at the University of Applied Science of Lippe and H_xter in Lemgo, responsible for meat technology. Addtionally he became Dean of the department food technology in 2002. His research and work areas are technology, sensory perception of food, meat production, ready-meals and convenience products as well as quality assurance concepts.

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Book Review

Standards for Engineering Design and Manufacturing

Author(s):

Dr. Wasim Ahmed Khan - Institute of Business Administration, Karachi, Pakistan

Prof. Abdul Raouf, S.I. - University of Management & Technology, Lahore, Pakistan

Detailed Description:

Most books on standardization describe the impact of ISO and related organizations on many industries. While this is great for managing an organization, it leaves engineers asking questions such as "what are the effects of standards on my designs?" and "how can I use standardization to benefit my work?" Standards for Engineering Design and Manufacturing provides hands-on knowledge for incorporating standards into the entire process from design bench to factory poor.

The book's five self-contained sections consider the scope of design and manufacturing, standards for the design of discrete products, standards for the manufacture of discrete products, standards for the use of discrete products, as well as support standards, The authors survey in detail the major standards-setting organizations and outline the procedure for developing standards. They consider standards from the perspective of product, equipment, and end-user, using this as a platform to explain the economic benefits of standardization. Case studies in every section illustrate the concepts and offer practical insight for using standards in CAD/CAM, selection of components, process planning, human/machine interaction, and computer interfacing.

With its modular approach and practical wisdom based on the authors' years of broad experience, Standards for Engineering Design and Manufacturing supplies the tools to incorporate standards into every stage of design and manufacturing.

UK Pound Price: 79.99

Published by:

CRC Press / Taylor & Francis Group, LLC, USA

6000 Broken Sound Parkway NW, Suite 3000, Boca Raton, FL33487, USA

Encyclopedia of Soil Science 2nd Edition

Author(s):

Rattan Lal - The Ohio State University, Columbus, U.S.A.

Detailed Description:

Provides complete information on chemistry, analysis, and evaluation of soils and geography and focuses on agricultural development in the third world, particularly through research on sustainable management of natural resource, soil productivity and environmental quality. Offers tools to restore and reinvigorate highly compromised soil. In detailed contributions from more than 400 esteemed international authorities across nearly 400 entries, plus over 1,000 illustrations, the encyclopedia:

- contains new sections on ISRIC-World Soil Information, root growth and agricultural management, nitrate leaching management, podzols, paramos soils, water repellant soils, rare earth elements, and much more
- presents hundreds of entries on tillage, irrigation, erosion control, minerals, ground water, and degradation
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- assesses the physical and hydrological properties of soil in natural and agricultural ecosystems

UK Pound Price: 340.00

Published by:

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270 Madison Avenue, New York, NY 10016, USA

Encyclopedia of Agricultural, Food, and Biological Engineering

Author(s):

Denis R. Heldman

Detailed Description:

The largest and most comprehensive guide on raw production technology with more than 3000 references and nearly 2000 photographs, figures, tables, and equations.

Examining the role of engineering in delivery of quality consumer products, this expansive source covers the development and design of procedures, equipment, and systems utilized in the production and conversion of raw materials into food and nonfood consumer goods-emphasizing and illustrating the various engineering processes associated with the production of materials with agricultural origin.

From forest and aquaculture products to biological materials and energy sources, the Encyclopedia offers step-by-step coverage of every system and application utilized in the production of agricultural crops and commodities-discussing tractors and implements, as well as current harvesting, handling, drainage, and irrigation techniques.

A distinguished panel of experts share a wealth of knowledge on:

- animal production systems, such as farm processing techniques
- storage and transportation of raw commodities
- the most recent developments in precision agriculture
- unit operations associated with food processing such as heating, cooling, freezing, thermal and nonthermal preservation, drying, and packaging
- regulatory requirements for cleaning and sanitation of equipment
- the handling and treatment of food wastes
- unique processes for biological materials including fermentation and separation

Published by:

Taylor & Francis Group

270 Madison Avenue, New York, NY 10016, USA

Engineering Principles of Agricultural Machines 2nd Edition

Author(s):

Ajit K. Srivastave - Michigan State University

Carroll E. Goering - University of Illinois

Roger P. Rohrbach - North Carolina State University

Dennis R. Buckmaster - The Pennsylvania State University

Detailed Description:

Others are now being taken for "Engineering Principles of Agricultural Machines,"2nd edition. New sections in this major update of the original text include an introduction to dimensional analysis, material on mechatronics, and a new chapter on precision agriculture. The book, which now includes a CD-ROM, gives practical discussions of functional components as well as the underlying theory. It covers equipment, components, and testing, with example problems and unsolved practice problems. The book will be ready for shipping January 13, 2006, but you can preorder now by calling 269/429-0300, or e-mail: martin@asabe.org

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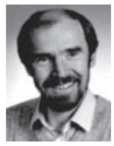
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