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EDITORIAL

We had an unusually warm winter season. It was also warm in Paris, France while visiting the SIMA show in March. We enjoyed the trip without a coat. If increasing greenhouse effect gas emissions from our economic activities caused this warm weather, urgent countermeasures are needed.

Continued economic growth in China and other developing countries, along with accelerated automobile production and increased population, resulted in an increasing demand for fuel. Under these circumstances, there is much expectation for recyclable energy throughout the world, and especially for biomass energy. Production of bio-ethanol from corn is rapidly increasing and has raised corn prices in the international market. This has caused a rise in feed grain price and has affected livestock farmers.

Mechanization of agriculture is basically a power-driven operation that consumes fossil fuel. We need to take two approaches to tackle these energy and environmental problems on the global level. One is to promote the utilization of recyclable energy and the other is to shift the life style toward less energy consumption. In Japan, life style in the days of the Edo-period is being reevaluated because it is environmentally kind and energy saving.

Utilization of biomass energy should be promoted in balance with food supply. Further food shortage in areas that are on the edge of starvation will worsen the situation. Considering that the market price of agricultural products has been controlled unfairly lower than that of other industrial products, it might be good from a macro point of view that the price of agricultural products rise with the discovery of the additional value as fuel. This is because unreasonably cheap agricultural biomass will accelerate the destruction of life systems.

Young people leave farms and go to cities to seek work that is more profitable. To engage in a primary industry that involves life systems is no longer attractive or profitable for them. It is being more and more popularized that cities have the power to provide the things required for their living. Life systems have been badly damaged while comfortable city life is enjoyed. It will be welcomed, in the long run, if trade conditions between the products of primary industry and those of other industries are improved.

The key issue in world agriculture is how to supply food to an increasing population with limiting farmland by maximizing land productivity. Agricultural machinery essential to this objective also needs energy. Our research effort toward minimizing this energy consumption for agricultural machines is expected. It has been a long time since the LISA Project was started in the United States. Their purpose and objective is widely recognized throughout the world. Intelligence technology is very useful for saving energy in agricultural mechanization. With the progress of electronic technology, development of intelligent agricultural machines has remarkably advanced. Intelligence technology makes it possible to know the appropriate working program that will provide maximum work with minimum energy. We should promote research on intelligence technology that will contribute to energy savings in agricultural mechanization.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
May, 2007

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Noise Levels in Indian Cotton Gins

by

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Abstract

Cotton ginning systems contain numerous types of machinery. Each is a source of noise and contributes to the overall noise level. Noise pollution in cotton gins has never received attention in the past in India. Noise levels of different machines used in cotton ginning systems were studied. The effect of noise on workers health and the possible ways of reducing the noise levels were suggested. Noise levels for double roller gins varied from 87.0 to 97.7 dBA under no load and from 85.9 to 97.7 dBA under load conditions. Noise for double roller gins was above permissible exposure limits of 85 dBA. The gearbox of the double roller gin generated more noise than other moving elements of the gin. Noise levels increased on a logarithmic basis. Noise levels of pre-cleaners and lint cleaners were to be below permissible exposure limits. In the press house, noise levels ranged from 79.3 to 93.5 dBA for different models of presses. The gin house was the noisiest workstation with an average noise level of 96.0 dBA. The noise level for the workstations such as raw cotton suction fan, pre-cleaner, gin house, central platform, seed blower and press operator room were above the permissible exposure limit. Exposure to such high noise levels could adversely affect their overall efficiency, safety, and hearing ability. Protecting the workers from loud noise by employing technical and personal measures of noise control could create healthful working conditions in gins.

Introduction

Ginning factories are in large number in India viz. over 4,000 units, which include roller and saw gins. Ginning factories are dispersed all over the nine cotton-growing states. In Punjab, Haryana, and Rajasthan cotton is mostly ginned with saw gins while in other states, viz. Gujrat, Maharashtra, Madhya Pradesh, Karnataka, Andhra Pradesh and Tamilnadu, the cotton is ginned largely with roller gins. Ginning is the first important mechanical processing operation that cotton undergoes on its way from field to the textile mills. Ginning without human intervention is quite impossible. In Indian gins, thousands of people are employed and they work under intolerable conditions. Accidents, fire hazards and health disorders are the usual happenings in the factories and are not investigated. The dust generated in the factories creates severe air pollution and leads to breathing problems and lung disorders. Noise generated in the factories is beyond tolerable limits.

Noise is commonly defined as unwanted sound and engineers classify it as wasted energy. Cotton ginning systems contain numerous types of machinery and each is a source of noise and contributes to the overall noise level. Exposure to such a noise may adversely affect their overall efficiency, safety, and hearing ability. People exposed to intense noise can experience stress related disorders and suffer temporary or permanent threshold shifts in hearing ability (Anthony and Laird, 1994).

Noise surveys of gins conducted in United States of America indicated that the noise levels inside the gins ranged from 95 to 99 dBA. Gin noises were usually in the frequency range of 31.5 to 250 cycles/sec, but many were in the range of 500 to 2,000 cycles/sec, which was most damaging to the human ear (Anthony, 1978). Some common sources of noise were lint cleaners, gin stands, vane axial fans, centrifugal fans and seed cotton cleaners, hydraulic pumps and motors. Dominant sources of noise in cotton gins were doffing brush noise in the 500 to 1,000 cycles/sec band, high frequency noise of air and cotton in the piping and low frequency noise due to rotating machinery parts and fan noise in the 125 cycles/sec band (Laird and Baker, 1982).

The effect of noise was not only

a reduction of the speed at which work was conducted, but also a decrease of accuracy in the work and high concentration for a longer period. Noise pollution in agricultural processing operations such as cotton ginning never received attention in the past in India. Central Institute for Research on Cotton Technology (CIRCOT) recently conducted an ergonomic survey of Indian ginneries and a study on the noise levels of the various machinery and workstations in the cotton gins. The objective of this study was to evaluate the noise levels of different machinery used in cotton ginning systems in India and to find out the effect of noise on workers health and suggest possible ways of reducing the noise levels.

Methods and Materials

The noise levels were measured by using a decibel meter (Model CE-8928) in dBA. The measurement range of the instrument was from 40 to 130 dB with 0.1 dB resolution. A weighted scale was used to measure the frequencies that the human ear could detect. Noise levels of widely used makes and models of double roller gin (DR1, DR2, DR3, DR4, DR5 and DR6), pre-cleaner (P1, P2, P3, P4 and P5), lint cleaner (L1, L2, L3 and L4), and F5) and baling press (BP1, BP2, BP3, BP4, BP5, BP6 and BP7) were measured. The noise levels were measured under load and no load condition of the machine. Noise was recorded at three different locations; (1) near the machine, (2) 7.5 m away from machine and (3) in factory premises at 30 m away from the machine. The noise levels were measured at the chest height in all the cases. Three replications were taken for each location, machine and operating condition. The average of three replications was recorded as the noise level for the particular machine. Noise generated by different moving parts of the double roller gin was measured by disconnecting the roller, beater and the gearbox.

The noise level in eight ginning factories at different workstations was measured. The measurements were made at 22 different locations in each factory. The selected factories were automatic and named as G1, G2, G3, G4, G5, G6, G7 and G8. The factories were automatic composite units conforming to the norms of Technology Mission on Cotton Mini Mission -IV (TMC MM-IV). These comprised 24 double roller gins with auto feeder, pre-cleaner, lint cleaner, baling press and automatic conveying systems for seed cotton, lint and cotton seeds. The conveying systems were either pneumatic or mechanical. During the noise measurement, all the machines were kept in operation. Three replications were taken at each workstation and in each factory. The average of three replications was recorded as the noise level at that location. The average noise level at each location for all the selected factories was also determined.

Results and Discussion

Noise Levels of Double Roller Gin Machines

The noise levels of different models of double roller gins are given in **Table 1**. The results showed that noise level near the gin for different models varied from 87.0 to 97.7 dBA and 85.9 to 97.7 dBA under no load and load condition, respectively. The noise levels at 7.5 m away from gin were between 77.0 and

Table 1 Noise levels of different makes and models of double roller gin machines

Model	Noise level, dBA					
	Under no load			Under load		
	Near gin	7.5 m away from gin	Factory premises	Near gin	7.5 m away from gin	Factory premises
DR1	88.0	83.0	65.5	86.6	82.7	62.9
DR2	87.3	80.1	65.8	87.0	79.7	64.6
DR3	87.0	77.0	66.5	85.9	76.7	66.1
DR4	97.7	81.5	63.3	91.6	77.4	60.4
DR5	96.7	87.4	68.1	97.7	87.5	68.4
DR6	93.9	84.9	68.0	93.2	83.2	64.4
Average	91.8	82.3	66.2	90.3	81.2	64.5

Table 2 Noise levels of different parts of double roller gin

Parts of DR gin	Noise level, dBA	
	Near gin	7.5 m away from gin
Gear box (Roller and beater are disconnected)	86.1	75.3
Roller and gear box (Beater is disconnected)	87.1	76.8
Gear box and beater (Roller is disconnected)	91.8	79.4

Table 3 Additive effects on noise under multiple noise sources

Machines in operation	Noise level, dBA		
	Under no load		
	Near gin	7.5 m from gin	Factory premises
One	87.2	84.6	66.4
Two	89.5	86.1	67.0
Three	90.4	88.0	67.5
Four	90.9	88.8	68.0
Five	91.2	89.5	68.5
Six	93.3	90.5	69.5
Ten	93.6	92.0	76.6

87.4 dBA and 76.7 and 87.5 dBA for no load and load condition, respectively. Noise level was greater under no load condition than the load condition. The average noise level for all the models was 91.8 dBA near gin machine and 82.3 dBA at 7.5 m away from the gin at no load condition. The average noise level for all the models was 90.3 dBA near gin machine and 81.2 at 7.5 m away from the gin at load condition. Noise levels were lower for the Jumbo model (roller length 1,365 mm) than for normal gins (roller length 1016 mm). Jumbo gins are the improved versions of the normal gins. Among the gins tested, DR1, DR2 and DR3 are the Jumbo gins and others were normal gins. Noise levels near the gin machines were above the permissible limit of 85 dBA.

Noise measurements were made on different parts of gin under no load condition (**Table 2**). The noise of 86.1 dBA was observed when only the gearbox was running and the roller and the beater had been disconnected. Noise level of 87.1 dBA was observed when roller and gearbox were running. Noise level of 91.8 dBA was observed when gearbox and beater were in operation. The results showed that the gearbox of the gin was noisier than the other moving parts of the gin.

The additive effect of noise was studied by switching on the gins one after another and the noise levels were measured. The data are presented in **Table 3**. Noise level increased on a logarithmic basis. Noise level increased sharply from 87.2 to 93.3 dBA when six gins were switched on. The increase in noise was at very slow rate when other gins were put into operation. The noise level was increased up to 93.6 dBA when ten gins were put into operation.

Table 4 Noise level of different makes and models of cotton pre-cleaners

Models	Noise level, dBA		
	Near machine	7.5 m away from machine	Factory premises
P1	69.7	62.3	57.4
P2	71.7	61.6	59.8
P3	80.1	71.7	64.1
P4	68.4	58.7	54.2
P5	70.6	63.3	58.6
Average	72.1	63.5	58.8

Table 5 Noise levels of different makes and models of lint cleaners

Models	Noise level, dBA		
	Near machine	7.5 m away from machine	Factory premises
L1	73.0	66.6	55.5
L2	74.8	72.0	59.5
L3	76.3	70.2	57.0
L4	73.3	66.6	63.4
Average	74.3	68.8	58.8

Table 6 Noise levels of baling press of different makes and models

Location in press house	Noise level, dBA						
	BP1	BP2	BP3	BP4	BP5	BP6	BP7
Lint suction fan/belt	95.1	79.6	78.1	79.8	72.5	75.3	93.3
Rams in operation	85.6	100.5	77.5	85.8	85.7	87.0	92.3
Tramper in operation	NA	NA	NA	78.5	80.5	87.5	93.4
Power pack	110.3	89.0	81.8	85.6	85.5	88.1	94.4
Operator/control room	94.2	88.5	78.1	78.7	85.5	85.0	93.5
Centre of press house	88.9	81.6	79.3	79.2	85.2	86.7	93.5
Outside the press house	73.4	69.9	66.3	64.4	73.3	78.0	82.7

Noise Levels of Pre-cleaners and Lint Cleaners

Five modes of pre cleaners were studied for noise measurement. The P1 and P2 were the inclined pre-cleaners with six cylinders and P3 with 5 cylinders. The P4 and P5 were the horizontal cleaners with 6 cylinders. Noise levels were varied from 68.4 to 80.1 dBA near the pre-cleaner, 58.7 to 71.7 dBA 7.5 m away from the pre-cleaner and 54.2 to 64.1 dBA in factory premises for the different models. The maximum noise level of 80.1 dBA was observed for P3 model of pre-cleaner. The average noise for the all models was 72.1 dBA near the pre-cleaner. The noise generated by the pre-cleaners was below the permissible exposure limit. **Table 4** shows the noise levels of different makes and models of pre-cleaner.

Four modes of lint cleaners were studied for noise measurement. The L1, L2, L3 and L4 lint cleaner models were the inclined type with 6, 5, 4 and 3 cylinders respectively. Noise levels varied from 73.3 to 76.3 dBA near the lint cleaner, 66.6 to 72.0 dBA 7.5 m away from the lint cleaner and 55.5 to 63.4 dBA in factory premises. The average noise level was 72.1 dBA near the lint cleaner. The L3 model of lint cleaner generated more noise than the other models. The noise generated by the lint cleaners was below the permissible exposure limit. **Table 5** shows the noise levels of different makes and models of lint cleaner.

Noise Levels of Baling Presses

Seven models of bale presses were studied for noise measurement. The BP1, BP2 and BP3 were the conventional double stage presses whereas the others were the automatic single stage presses with automatic tramping facility. The noise levels were measured during different unit operations of bale pressing. The noise levels are given in **Table 6**. Noise levels were between 79.3 and 93.5 dBA in the center of the press house for different makes. Noise level for different makes varied from 77.5 to 100.5 dBA while rams were in operation. In the operator room, the maximum noise of 94.2 dBA was observed for BP1 bale press. The power pack was found to generate noise up to 110.3 dBA for BP1 bale press. The noise level outside the press house ranged from 64.4 to 78.0 dBA. Noise levels of baling presses of different make and models are shown in **Table 6**.

Noise Levels at Different Workstations in Cotton Gins

The noise levels at different workstations in various factories are given in **Table 7**. The average noise level for all the factories near factory gate, office, weigh bridge, staff quarters and cotton heaps ranged from 62.3 to 66.1 dBA. The average noise generated by the raw cotton suction fans was 88.2 dBA. The noise level was above the permissible limit of 85 dBA for the workstations such as raw cotton suction fan, pre-cleaner, center of gin house, central platform, end of gin house, seed blower and in press operator room. A maximum average noise level at the gin house was 96.0 dBA. The noise levels at the center of the gin house for the different factories ranged from 92.5 to 98.5 dBA. The noise levels at the center of press house for the different factories ranged from 72.5 to 93.5 dBA with an average of 83.5 dBA. The noisiest workstations were found to be the gin house, central platform, raw cotton suction fan, pre-cleaners, press house and seed blower. The average noise levels of all the workstations for all the factories were 78 dBA. **Fig. 1** shows the view of gin house while measuring noise level.

Conclusions

Noise levels for double roller gins varied from 87.0 to 97.7 dBA under no load and from 85.9 to 97.7 dBA under load condition. Noise for double roller gins was above the permissible exposure limit of 85 dBA. The gearbox of the double roller generated more noise than other moving elements of the gin. This will call for appropriate remedial measures such as the regular maintenance and replacement of worn out parts, muffle the noise by using dampening materials and replace the components that are more noisy. Noise levels increased on a logarithmic basis. Noise levels of pre-cleaners and lint cleaners were below the

(continued on page22)

Fig. 1 View of gin house while measuring noise level

Table 7 Noise level at different work-stations in ginning and pressing factories

Work-station	Noise level, dBA								
	F1	F2	F3	F4	F5	F6	F7	F8	Avg.
Factory gate	85.4	66.5	66.2	57.8	67.3	60.8	54.5	57.8	64.4
Office	72.7	68.1	67.3	57.8	73.5	66.4	55.2	57.8	64.8
Staff quarter	-	59.4	65.0	-	73.5	66.4	53.8	-	63.6
Weigh bridge	56.7	66.8	70.7	58.2	67.3	60.8	60.0	58.2	62.3
Kapas heaps	60.6	64.7	60.8	74.2	66.6	75.1	60.4	66.8	66.1
Mouth of suction pipe	58.5	77.1	74.2	76.4	66.9	76.8	79.0	80.8	73.7
Raw cotton suction fan/cyclone room	89.1	99.5	81.5	82.5	85.4	82.8	87.0	97.7	88.2
Pre-cleaner	93.8	95.1	83.9	80.0	90.8	80.5	82.8	95.7	87.8
Central platform	92.4	-	90.5	-	88.7	91.1	-	-	90.7
Centre of gin house	97.8	98.5	97.2	96.3	96.6	92.5	93.7	95.7	96.0
End of gin house	93.4	86.9	91.4	85.8	88.7	89.3	91.2	85.4	89.0
Lint cleaner	77.5	87.7	82.6	78.0	84.5	-	91.3	-	83.6
Lint suction fan (gin)/cyclone room	79.1	94.1	85.6	-	85.9	68.1	74.4	-	81.2
Pala house	72.3	87.0	76.5	77.9	82.2	68.1	-	-	77.3
Lint opener	79.6	-	82.3	-	-	-	-	-	81.0
Lint suction fan (press)/cyclone room	-	95.2	-	75.5	85.9	72.5	75.3	96.8	83.5
Seed blower pit/seed bucket elevator	87.6	87.8	80.5	86.6	86.6	88.1	85.7	94.5	87.2
Seed heap	65.7	68.4	65.3	68.8	78.0	68.3	64.6	73.3	69.1
Centre of press house	72.5	89.1	79.0	82.7	79.2	85.5	86.7	93.5	83.5
Press opetator room	81.0	93.8	78.1	85.6	78.7	85.2	85.0	93.5	85.1
Temporary bale storage	69.9	73.4	66.6	74.1	73.3	73.3	78.0	82.7	73.9
Bale godown	-	59.3	72.4	-	-	-	-	-	65.8

Evaluation of Hydraulic Energy Nozzles Suitable for Orchard Spraying

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Abstract

Manually operated sprayers are mostly used at present for orchard spraying. In a spray nozzle, is an important component which determines its performance. In manually operated sprayers, generally hydraulic energy nozzles are used. This evaluation was done to identify the suitable energy nozzle for orchard spraying. Commercially available hydraulic energy nozzles (NMD/S, BAN, Broad cone, NMM, NTM) used for orchard spraying were selected for the study. The discharge rate, droplet size and density and height of reach of all the types of nozzles were measured with a pressure range of 1.5 to 3 ksc at an interval of 0.5 ksc, 0, 30, 45 and 60 degree orientation and 50, 100 and 150 cm horizontal distances using experimental setup. The discharge rate of nozzles increased with increasing pressure. The NTM nozzle recorded a maximum discharge rate of 81.8 lit/hr at 3 ksc operating pressure followed by a broad cone nozzle (74 lit/hr). The broad cone and NTM nozzles at horizontal distances of 150 cm and 45 degree orientation gave maximum height of reach and uniform spray of droplets within 113 µm among the nozzles tested. Based on the volume distribution of droplets, a broad cone nozzle at 45 degree orientation with 100 cm horizontal distance resulted maximum height of 105 cm at which 50 % volume of spray was deposited. At this height droplet size was 150 µm.

Introduction

In India cropped area under fruits occupies 3 % of the total cultivated area and share about 14 % of total pesticide consumption. A striking feature of Indian orchards is the small size of the individual holdings. The predominance of very small orchards increases the difficulty of introducing better methods of pesticide application. The broad aim of pesticide application is to maximize control of the pest organisms with use of a minimum amount of pesticide, and to minimize the amount of loss to off-target areas. If the amount of material required for maximizing pest control can be reduced, more effective application of the pesticide to the target can be accomplished. A pesticide needs to be applied to the particular "target" area affected by insects, pest and diseases. Manually operated sprayers are mostly used at present for orchard spraying. In a spray nozzle is an important component which determines its performance. In manually operated sprayers, generally hydraulic energy nozzles are used. This evaluation was done to identify the most suitable energy nozzle for orchard spraying. Thus, it will help the farmers to reduce the waste of chemicals along with effective control of pests and diseases.

Review of Literature

Discharge Rate

Nordby and Haman (1965) stated that a solid cone nozzle gives better results of spraying than hollow cone nozzle. The coverage deteriorates with decreasing cone skin thickness.

Shukka et al. (1987) found that the average nozzle discharge varied from 0.458 lit/min to 0.820 lit/min as the pressure was increased from 2.0 to 4.0 ksc.

Droplet Size

Yeomans (1952) reported that control of forest defoliators was satisfactory with an NMD of 275 µm. Davis et al. (1956) tested sprayers with a NMD of 80, 150 and 300 µ m for the control of the spruce bud worm choristoneura fumiferana (clemens) and concluded that an NMD of 300 µm was effective in controlling the spruce bud worm choristoneura fumiferana.

Regupathy and Dhamu (1990) described the method of determination of droplet size. Droplets are collected on suitable surface on which a mark, crater or stain is left by their impact. The difference between the mark, crater or stain and the true size is the spread factor. The standard surface used to collect droplets was magnesium oxide (MgO); glass slides coated with burning magnesium ribbon. The magnesium oxide surface is less satisfactory for small droplets and those above 200 µm may shatter on impact. No spread factor is needed for grease matrix, as the droplets resume their original spherical shape on this surface. The above mentioned surfaces are difficult to use in the field. Hence glassy paper such as kromekote or photographic papers were used. The spray is colored with a water soluble (e.g. Methylene blue - 0.75 %) or oil soluble (e.g., Croceine scarlet) dye according to the spray liquid use.

Mathews et al. (1982) reported the desirability of using droplet size of 30 to 100 µm diameter to increase deposition on plant leaves. Akesson and Yates (1989) stated that droplet of 100 to 200 µm diameter are most effective for control of bush and other plant species.

Ramesh Babu et al. (1990) found that the droplet size in pressurized sprayers was observed to be 150 to 190 µm. In all the sprayers 30 to 50 cm height of application was observed to give good performance of deposition efficiency.

Materials and Methods

Selection of Nozzles

The following commercially available hydraulic energy nozzles used for orchard spraying were selected for the study. The specifications of the nozzle are given in **Table 1**.

Determination of Discharge Rate

The discharge rate of the nozzle was tested for pressure range of 1.5 to 3 ksc at an interval of 0.5 ksc. The discharge liquid was collected for a period of 1 minute in a measuring jar of 1 lit capacity. The total volume of water was measured and discharge rate was calculated.

Determination of Droplet Size

The most widely used parameters to represent droplet size are the volume median diameter (VMD) and the number mean diameter (NMD) measured in micro meters (µm). Droplets are collected on photographic paper. The spray is coloured with water soluble methylene blue of 0.75 % concentration. The droplets size was measured with a microscope equipped with an ocular recticle after allowing a minimum period of 24 hrs

Table 1 Specification of the selected nozzles

Commercial code	Type	Orifice diameter, mm
NMD/S	Solid cone	1
BAN	Solid cone	0.5
Broad cone	Hollow cone	2
NMM	Solid cone	0.5
NTM	Solid cone	2

Table 2 Discharge rate of nozzles

Nozzle	Discharge rate, lit/hr			
	1.5 ksc	2 ksc	2.5 ksc	3 ksc
NMD/S	24.7	26.6	28.8	30.8
BAN	22.4	24.2	25.9	28.0
Broad cone	54.2	61.8	68.6	74.2
NMM	19.8	22.2	24.5	27.0
NTM	68.0	72.2	74.0	81.8

The following parameters were measured using experimental setup.
a. Discharge rate, b. Droplet size and density, c. Height of reach

Fig. 1 Effect of dischage rate on pressure

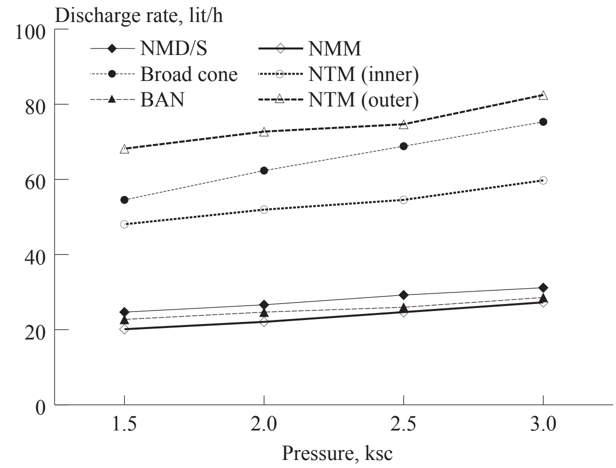
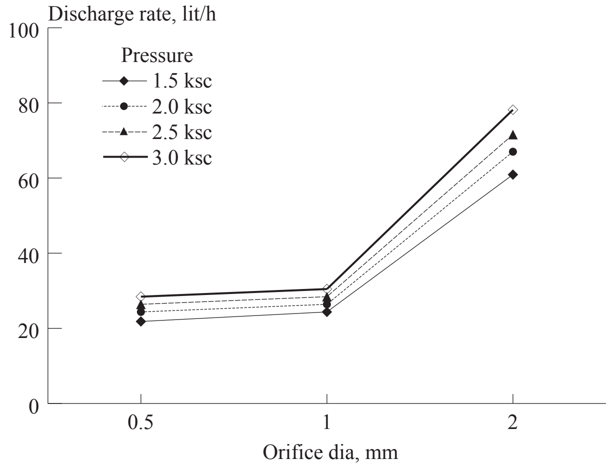


Fig. 2 Effect of dischage rate on orfice diameter



for complete spreading of droplets on the sampling surfaces.

The droplets were collected at a vertical interval of 25 cm and a horizontal interval of 25 cm distances. By using this arrangement the height of reach was also measured. The distance between the nozzle and photographic paper was selected to be 50, 100 and 150 cm. The nozzle orientation was kept at 0, 30, 45 and 60 degrees. The nozzle was fixed at 50 cm above the ground level.

Results and Discussion

Discharge Rate

The discharge rate of 5 types of nozzles with different operating pressures are presented in **Table 2**.

Effect of Pressure on Discharge Rate

The discharge rate for all types of nozzles was directly proportional to pressure. Irrespective of pressure charge the NTM nozzle recorded maximum discharge rate of 68 to 81.8 lit/h followed by broad cone nozzle (54 to 74 lit/h). The discharge rate of the nozzles gradually increased with increase in pressure (**Fig. 1**).

Inter relationship between orifice diameter and discharge rate

The discharge rate was measured for nozzles in different orifice diameter viz. 0.5, 1.0, and 2.0 mm. **Fig. 2** illustrates the relationship between the discharge rate and orifice diameter of the nozzles. The results indicate that generally the discharge rate increased with the increasing orifice diameter for all the operating pressure. The variation in discharge rate was minimum for the orifice diameters of 0.5 and 1.0 mm where as the variation was maximum when the orifice diameter increased from 1 to 2 mm.

Droplet Distribution

Droplet distribution was measured with the number mean diameter (NMD) and volume mean diameter (VMD) for the test nozzles.

Number Median Diameter

The number mean diameter (NMD) was calculated for all nozzles with 0, 30, 45 and 60 degree orientation and 50, 100 and 150 cm horizontal distances. The average NMD and coefficient of variance for each nozzle orientation was summarized in **Tables 3** to **6**. From the **Table 3** it was observed that the NMD/S nozzle with a horizontal distance of 150 cm and 30 degree nozzle orientation gave more uniform droplets distribution with a CV of 0.1 with average NMD of 126.23 µm. The broad cone nozzle gave best performance at 150 cm horizontal

Table 3 NMD for NMD/S nozzle

Distance, cm	Angle, deg.	NMD, µm								Average NMD, µm	CV
		-50	-25	0	25	50	75	100	125		
50	0	77.92	157.02	122.34	186.58	-	-	-	-	139.99	0.34
	30	-	-	129.34	125.57	156.89	159.56	-	-	147.34	0.12
	45	-	-	177.84	156.35	206.33	132.52	-	-	168.26	0.18
	60	-	152.29	164.81	200.89	125.71	188.56	325.44	-	192.94	0.36
100	0	86.42	142.29	124.26	162.32	-	-	-	-	100.75	0.56
	30	-	-	157.02	268.53	270.74	313.64	205.38	-	243.06	0.25
	45	-	120.03	191.26	238.26	219.08	230.01	-	-	199.72	0.24
	60	-	149.73	146.60	86.64	92.31	-	-	-	118.82	0.28
150	0	-	241.74	615.42	-	-	-	-	-	428.58	0.61
	30	-	109.82	134.77	122.77	121.35	143.04	-	-	126.23	0.10
	45	-	-	94.08	152.37	92.62	85.92	59.73	-	96.84	0.35

Table 4 NMD for Broad cone nozzle

Distance, cm	Angle, deg.	NMD, µm								Average NMD, µm	CV
		-50	-25	0	25	50	75	100	125		
50	0	123.48	176.29	111.32	114.48	-	-	-	-	131.39	0.23
	30	-	-	183.58	143.44	146.21	271.71	-	-	186.23	0.32
	45	-	170.22	114.42	158.29	118.88	64.15	-	-	125.19	0.23
	60	-	127.32	141.03	171.89	203.71	182.78	134.46	101.37	151.68	0.23
100	0	204.51	224.09	117.50	297.09	258.79	-	-	-	220.30	0.30
	30	-	206.98	255.63	271.26	97.91	78.73	-	-	183.30	0.49
	45	-	103.58	141.74	199.24	161.01	107.51	115.08	159.86	141.16	0.24
	60	-	189.22	143.42	121.35	188.27	97.92	67.71	-	134.64	0.36
150	0	141.24	103.63	69.85	397.26	-	-	-	-	177.79	0.83
	30	-	168.81	88.17	262.46	122.61	120.46	-	-	52.50	0.44
	45	-	105.92	130.35	100.31	106.55	100.22	128.26	87.97	108.51	0.14

distance and 45 degree orientation with NMD of 105 µm and CV value of 0.14. In this combination height of reach was also maximum. For the NMM nozzle the best performance was obtained with a horizontal distance of 100 cm and 0 degree orientation with the average NMD of 124.83 µm and CV of 0.18, but the height of reach was minimum.

In the case of NTM nozzle, the best performance was obtained at the horizontal distance of 150 cm and 45 degree orientation with a CV of 0.14 and 118 µm NMD value with maximum height of reach. It was concluded that the broad cone and NTM nozzle at a horizontal distance of 150 cm from the target and 45 degree orientation of the nozzle resulted in maximum height of spray with the droplet size of 113 + 5 µm with CV of 0.14. These nozzles are suitable for orchard spraying among the nozzles tested.

Volume Distribution of Droplets

The volume of spray was calculated by multiplying the number of droplets with the volume median diameter (VMD). From this data the height at which 50 % volume of spray deposited was calculated. Graphs were drawn between the calculated height of 50 % volume spray deposited and the horizontal distance between the nozzles and target (**Figs. 3** to **6**).

The maximum height of spray was obtained when orientation of the nozzle was at 45 and 60 degrees. The height of spray gradually increased from 0 degree orientation of the nozzle to 45 degree for all nozzles. Spray above that the height of reach was not appreciable. Hence the spray nozzles should be oriented at 45 degree for orchard spraying to obtain maximum spray volume and height.

The NMD values of 50 percentile volume height was calculated and presented in table.8. It was observed that for the broad cone and NTM nozzle the NMD value at 50 percentile volume height for 45 degree nozzle orientation was almost equal. For NMD/S and NMM nozzles it was not uniform in any orientation. Among the nozzles tested the broad cone nozzle at 45 degree orientation with 100 cm horizontal distance resulted maximum height of 105 cm at which 50 % volume of spray deposited. At this height droplet size was 150 µm.

Conclusions

- The discharge rate of nozzles increased with increasing pressure. The NTM nozzle recorded maximum discharge rate of 81.8 lit/hr at 3 ksc operating pressure followed by the broad cone nozzle (74 lit/hr).
- The broad cone and NTM

Table 5 NMD for NMM nozzle

Distance, cm	Angle, deg.	NMD, µm								Average NMD, µm	CV
		-50	-25	0	25	50	75	100	125		
50	0	104.49	131.50	156.89	196.72	-	-	-	-	147.42	0.26
	30	-	150.23	162.81	169.17	122.38	261.33	-	-	173.20	0.38
	45	-	184.26	68.43	186.97	151.22	120.20	83.48	-	132.92	0.31
	60	-	93.20	111.04	139.75	145.96	100.54	179.37	-	128.31	0.25
100	0	145.88	93.97	122.38	137.12	-	-	-	-	124.83	0.18
	30	-	184.26	87.51	205.16	226.07	71.53	446.68	-	209.39	0.72
	45	-	206.35	97.37	167.38	168.52	270.79	156.20	-	177.76	0.32
	60	-	102.42	124.06	87.53	72.93	-	-	-	96.73	0.22
150	0	109.20	148.82	80.21	-	-	-	-	-	96.07	0.62
	30	-	225.78	112.26	114.82	156.26	-	-	-	152.28	0.34

Table 6 NMD for NTM nozzle

Distance, cm	Angle, deg.	NMD, µm								Average NMD, µm	CV
		-50	-25	0	25	50	75	100	125		
50	0	120.32	168.02	184.28	183.77	-	-	-	-	164.14	0.18
	30	-	-	90.42	128.46	186.38	346.72	-	-	187.84	0.59
	45	-	125.05	130.62	172.53	198.59	108.10	293.78	-	171.39	0.40
	60	-	-	106.47	101.99	168.85	200.52	134.48	118.86	138.52	0.28
100	0	192.08	147.32	274.11	349.70	-	-	-	-	240.80	0.37
	30	396.89	160.02	248.12	174.26	262.45	-	-	-	268.34	0.44
	45	-	108.12	173.72	230.01	180.57	210.48	135.01	77.53	159.35	0.34
	60	-	129.09	153.93	190.92	86.65	181.92	245.95	174.06	167.50	0.29
150	0	176.73	119.32	80.13	-	-	-	-	-	125.35	0.38
	30	144.25	125.10	113.25	111.17	73.46	64.11	-	-	117.55	0.36
	45	-	78.39	119.98	148.01	122.65	117.39	97.89	122.11	118.01	0.14
	60	-	-	97.91	126.46	84.12	61.42	54.22	83.61	90.45	0.21

nozzles at horizontal distances of 150 cm and 45 degree orientation gives maximum height of reach and uniform spray of droplets within 113 µm among the nozzles tested.

- Based on the volume distribution of droplets, the broad cone nozzle at 45 degree orientation with 100 cm horizontal distance resulted maximum height of 105 cm at which 50 % volume of spray deposited. At this height droplet size was 150 µm.

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Fig. 3 Effect of distance on 50 percentile volume height NMD/S nozzle

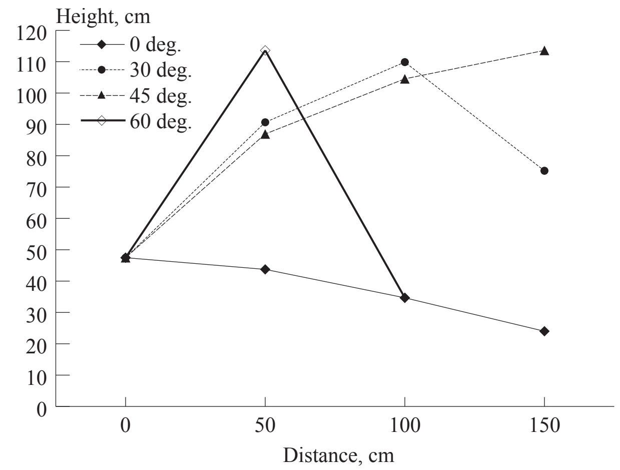


Fig. 4 Effect of distance on 50 percentile volume height broad cone nozzle

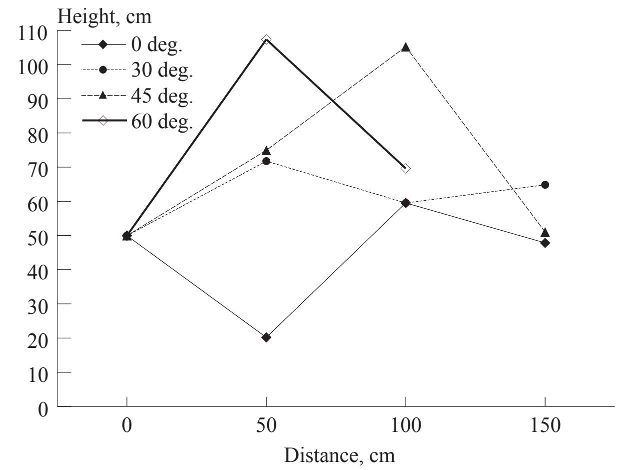


Fig. 5 Effect of distance on 50 percentile volume height NMM nozzle

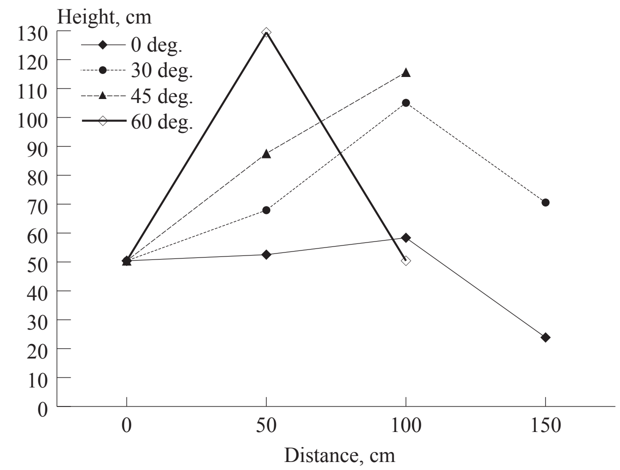
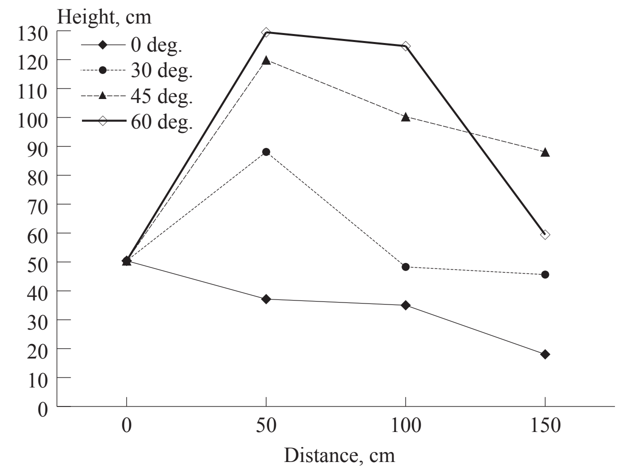


Fig. 6 Effect of distance on 50 percentile volume height NTM nozzle



An Innovative Vertical Axial-flow Threshing Machine Developed in China

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Backgound

Farmers in developing countries urgently need low cost harvesting machinery that they can buy within their purchasing power to minimize the drudgery and harvesting labor consumption. Based on this fact, the author has spent his life developing the Vertical Reaper and the Vertical Axial-Flow Threshing Machine. It is believed that such an idea could make the machine much simpler and cheaper. After the invention of the vertical reaper was successful in 1975, produced in China, and later introduced into Southeast Asian countries, it continued to follow the "vertical" idea. The research on the Vertical Axial-flow Threshing (VAFT) machine began in 1977. Since then, the investigation has gone through three stages: First: To find the working possibility when the cylinder is erect, (1977-1979). Second: To investigate the functions of various working parts by modern testing methods such as the radio-isotope 60 cobalt tracing method to explore the crop movement in the cylinder (1978-1986). Third: To design and make a prototype vertical thresher for field test, step by step, and to improve its working parts. (**Fig. 3**) (1986-1992). Later, in order to meet combine requirements, a large VAFT unit with a feed rate of 2 kg/s was made and tested in cooperation with the Prairie Agricultural Machinery Institute at Humboldt, Canada (**Fig. 2**) in 1995. However, until 1999, the same capacity prototype VAFT combine, semi-mounted on a tractor, was born and tested in Beijing (**Fig. 1**). Generally speaking, all the testing results proved its superior performance over what we expected, although some parts, also, could be improved.

This paper covers a summary of research work of the VAFT machine with an analysis of its performance.

The author would like to present this technology to the public, and contribute the details and drawings to any person or enterprise interested in this new machine.

Strong Threshability of the VAFT Machine

A cross sectional sketch of the VAFT machine with its parts list is shown in **Fig. 4**. There are two reasons why the VAFT machine could reach perfect threshability:

1. The vertical cylinder of the VAFT is composed of three kinds of teeth. (1) Feeding blade teeth; (2) V-type threshing teeth; and (3) U-type separating teeth. There are

Fig. 1 VC2 vertical axial-flow combine working in the field

Fig. 2 VC2A vertical axial-flow threshing unit made in Prairie Agricultural Machinery Institute, Canada

Fig. 3 VT1.0 vertical thresher worked in the field

a total of 92 pieces. It was found that the threshing action of the axial-flow cylinder was mainly due to the high frequency of teeth impact, combined with the rubbing and stripping action to the crop kernels. It is quite different from the cross flow cylinder that applied only one sudden fierce impact to the crop. Therefore, for the VAFT machine, the more teeth impact to the kernel, the better threshing. To find the frequency of random impact to one head by 92 teeth, the test was made that while the sample of a simulating stem with a false active head revolved 3 to 4 revolutions and dwelled 1 to 1.5 seconds in the cylinder, the head was beaten 30 to 45 times by the teeth. No doubt, such excess repeated impact to the grain head would guarantee the perfect threshing (100%). Even with the hard-to-thresh Japonica rice or not matured green wheat, they are fully threshed each time.

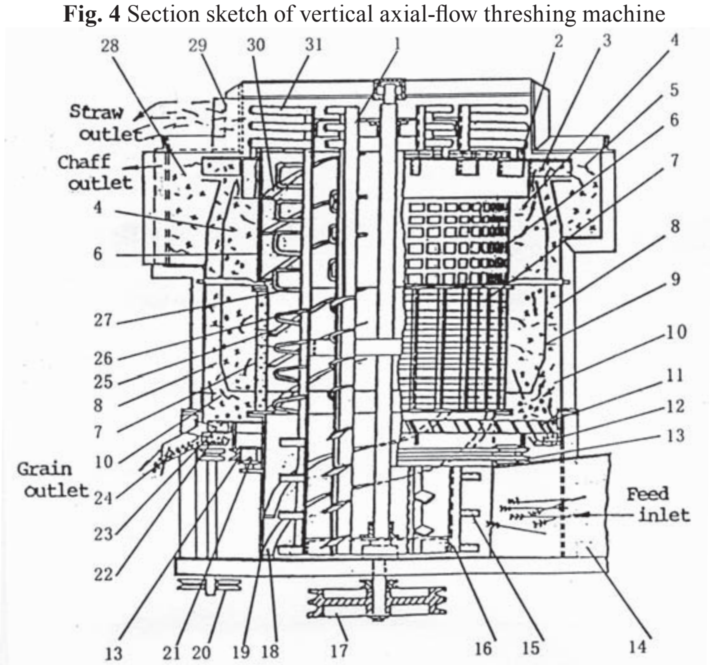
The excessive teeth strike to the crop may cause more straw breaking. But the short straw through the concave grate can be reduced by redesign of the concave.

2. In laboratory tests, it was found that the function of the feeding blade teeth at crop-feed entry was, not only to convey the crop immediately moving upward to prevent clog in feed opening, but, also, produced strong threshing action. **Table 1** shows the cylinder threshing rate relevant to cylinder length (the height). The feeding teeth threshed 79.01 % of the wheat and 71.6 % of the rice. As a result of the pre-threshing function, the threshing section of the cylinder could be made shorter and, also, the threshing concave could have efficient separation. The advantage of this function will be explained later.

Table 1 VAFT cylinder threshing characteristics VS cylinder length (wheat 1982)

Moisture content		Feed rate, kg/s	Cylinder hei ht		Threshing eff., %
Seed	Straw		Section	mm	
12 %	14 %	4	Concave section	800-900	96.49
				600-800	93.91
				400-600	89.20
			Feed section	D-4DD	79.01

Fig. 4 Section sketch of vertical axial-flow threshing machine



1: Cylinder bar, 2: Fan fixed joint, 3: Hollow-type suction fan, 4: Threshed material compartment, 5: Outlet air channel, 6: Separation concave, 7: Threshing concave, 8: Vertical air duct, 9: Inner wall of air duct, 10: Air entrance, 11: Dispersing wheel, 12: Grain pan, 13: Dispersing wheel drive, 14: Feed opening, 15: Blade feeding teeth, 16: Cylinder assembly, 17: Driving sheave, 18: Feed-chamber loop guide, 19: Feeding chamber, 20: Counter shaft, 21: Roller, 22: Grain scraper, 23: Dispersing blade, 24: Grain outlet, 25: Thresh concave loop guide, 26: V-type threshing teeth, 27: U-type Separating teeth, 28: Chaff outlet, 29: Straw outlet, 30: Separation concave loop guide, 31: Straw through-out teeth

Superior Separation Characteristics of the VAFT Machine

Every one knows that the capacity of grain separation through the concave grate is proportional to its area. The larger the concave area the higher the separation efficiency, eventually resulting in less grain loss. Since the VAFT machine has the advantage of 360º circular concave, its area is twice as large as the horizontal axial-flow with the same concave length. In addition, the actual concave area of the VAFT is designed much bigger than needed. For example, the total concave area of prototype VC2 vertical threshing combine (**Fig. 1**, feed-rate 2 kg/s) is as large as 2.965 m^2 (threshing concave 1.175 m^2, separating concave 1.790 m^2). To compare with an equivalent throughput of Xing-Jiang-2 combine produced in China, its total concave area is only 0.92 m^2. The VC2 is 2.2 times larger than that. We also compare with the U.S. Case 1620, a larger longitudinal axial-flow combine with a concave area 20 % less than the VC2.

Because theVAFT machine has such excess concave separation area, it has almost zero separation grain loss. Furthermore, when sudden overloads or wet crop conditions are encountered in field harvesting, the VAFT has potential capability to overcome the immediate field loss.

Table 2 shows the laboratory testing results of concave separating performance and separating density distribution along concave length. In testing, the concave was divided into eight sections. A round partition box collected the threshed materials from each section.

In order to compare the concave separation performance of the VAFT machine with those of horizontal axial-flow cylinder, two samples were chosen from two other colleges that had investigated these units for several years. Three comparable cylinder structures are shown in **Fig. 5**. The testing results of concave performance from the two other colleges were abstracted from their annual reports. All testing data from three kinds of cylinders were converted into plot curves and shown in **Figs. 6** and **7**. The following observations were made to compare the concave separating performance curves in **Figs. 6** and **7**.

1. **Fig. 6** and **Table 2**, indicate that the VAFT curve 1 reached a large separation (62.63 %) at the concave entrance within 100 mm intervals. It had the largest separation rate among the three cylinders. The reason that the VAFT had such a large separation rate was because of the high pre-threshing function in the feeding chamber that had already threshed 79.01 % of the grain. The advantage of such a feature allowed the threshing concave to get most separation efficiency. Therefore, the curve formed an exponential function with a high exponent.

Curve 2 represents a propeller-feed type cylinder. Because it had less pre-threshing action at the concave entrance of 230 mm intervals, the separation was as low as 24.26 %. Curve 3 represents auger-feed type cylinder. The auger has little pre-threshing action. (The auger was positioned inside the concave.) The separation at the concave entrance within 300 mm interval is only 16.8 %.

2. The curves of **Fig. 7** represent the separation density distribution versus concave length. In VAFT curve 1 the peak density (62.63 %) occurred at the concave entrance and then dropped rapidly with an exponential decay function. This is another illustration to identify that the VAFT concave has the most efficient separation function due to the merit of high pre-threshing action and 360º circular concave design. The cylinder length, therefore, could be made shorter. The peak density for curve 3 is retarded to 862 mm concave length. This meant that the concave area before 862 mm had not been efficiently utilized in separation. Therefore, the concave needs to be longer.

Higher Quality Grain from the VAFT Machine

We believed we could reduce the cylinder linear speed about one-third since grain threshing by the VAFT is achieved by excessive high frequency beating of cylinder teeth (from the usual 30 m/s to 20-22 m/s). This will produce lighter impact force on the grain head. The kernel may not be detached from the grain head by the first or second strikes, but it will possibly be removed from the head by several strikes for the resultant complete threshing (This was identified by slow motion pictures [6]). The physical phenomena of the kernel being gradually released from the grain head appears to be fatigue break down. This was called the principle of “Fatigue Threshing”. The quality of threshed grain was greatly improved, because the slower cylinder speed gave a gentle impact to the kernels. When threshing rice, there were no broken kernels or husked rice as found with the cross-flow combine. With wheat there was no kernel damage and no reduction in the germination of the grain, as found with the rasp bar cylinder. These positive effects of the slower cylinder speed of the VAFT machine were proven by many tests.

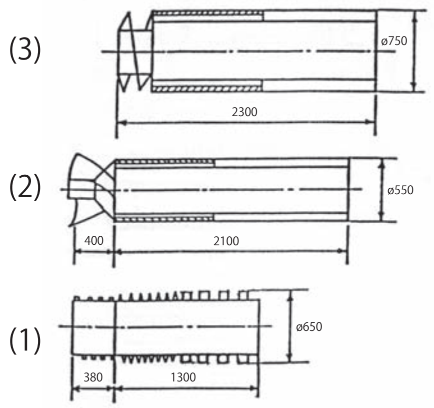
Unique Pneumatic Cleaning System Used in VAFT

Many people in China have tried the air-cleaning method in the small thresher, because of the simplicity of the machine. However, such cyclone cleaning method cannot avoid

Table 2 VAFT concave separation characteristics VS concave height (wheat 1982)

Feed rate	Partition box no.4	Concave accumulative height, mm	Caluclated height, mm	Accumulative separation rate, %	Density % distribution at each section
4 kg/s	8	1000-1500	1057	100	0.05
	7	850-100	925	99.95	0.23
	6	700-850	775	99.72	0.08
	5	550-700	625	99.54	1.20
	4	400-550	475	98.44	2.94
	3	250-400	325	95.50	9.23
	2	100-250	175	86.27	23.64
	1	0-100	80	62.63	62.53

Fig. 5 Three comparable cylinder



(1) CAAMS vertical axial-flow threshing unit
(2) Lue-Yang engineering college horizontal axial-flow threshing unit
(3) Northeastern agricultural college horizon -tal axial-flow threshing unit

grain loss if the required cleanness is achieved.

The air cleaning system used in the VAFT is quite different. It is based on the principle that each component of the material has a different suspending coefficient. Each component such as grain, chaff and short straw has its own terminal (critical) velocity. If a definite air velocity is set in a vertical air duct, the lighter material will be lifted up and drawn out, and the heavy material will drop down. Fortunately, the VAFT has the advantage of a vertical duct to separate trash and chaff. The terminal velocity of separate materials is:

- Rice: 10.1 m/s
- Chaff and trash: 0.6-5.0 m/s
- Wheat: 8.9-11.5 m/s
- Short straw: 2.5-3.2 m/s

(Short straw less than 100 mm with its axis perpendicular to the vertical airflow)

As shown in **Fig. 4**, an outer circular air duct, 8, is surrounding the vertical grain separation compartment, 4. At the upper end of the air duct, there is a large circular suction fan, 3, to generate airflow upward through the bottom of the duct opening. The air velocity at the duct opening is set at 7.5 m/s. During the concave, separating materials came from the circular concave grate and fell to the bottom on a rotating dispersing wheel, 11, all the chaff, trash and short straw with terminal speeds less than 7.5 m/s, were sucked through the duct opening and thrown out by fan blades. The grain, which has a terminal speed greater than 7.5 m/s, dropped through the wheel blade into the grain pan, 12, and were scrapped out by wheel scrapper.

Because the opening area of circular duct was very large (0.553 m^2), and the quantity of air flow was much more than needed to convey the chaff and trash, the air cleaning system was very strong.

Nevertheless, such an air cleaning system has certain unsatisfactory characteristics. If there are some shriveled grains or lighter grains in harvesting the field, they could be drawn out by air and counted as field losses. Second, because the short straw is not spherical, its terminal velocity varies according its position in the air duct. A small amount of short straw may fall into grain pan and mix with grain. But by adding a rotary screen grain separator, it is easy to separate the short straw from clean grain.

The VAFT Machine is Made of Simple Parts

Besides the superior threshing and separation performance, the other special features of the VAFT machine are its simple working parts, as described in the following:

1. Simple transmission: There are only two shafts that transmit power to the cylinder and revolving dispersing wheel. There are no reciprocating moving parts. All parts are easy to make.
2. Re-threshing system is not needed.
3. No adjustment is required while working. The concave clearance is fixed. The cylinder and suction fan speed are constant.
4. A straw cutter and spreader are omitted because the short straw is thrown out from the top outlet of the concave and will evenly distribute in the field.
5. Because the cylinder set is vertical, the whole threshing unit is more compact and occupies less space than longitudinal and horizontal type combine, hence, the maneuverability is better.

Conclusion

A new concept of Vertical Axial-Flow Threshing Machine was developed and has been investigated for many years. Its superior threshing and separating performing characteristics to reduce grain losses and increase grain quality have been analyzed. The structure of the

Fig. 6 Grain separation rate vs concave length

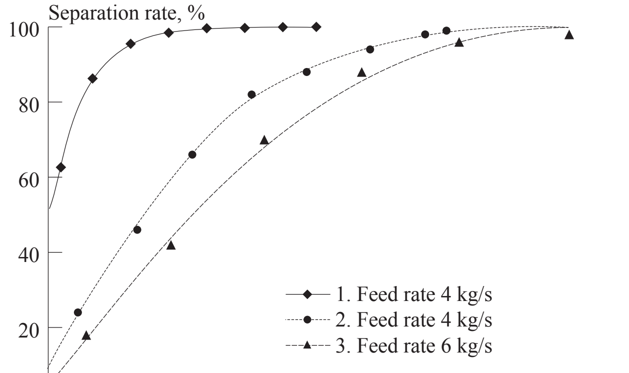
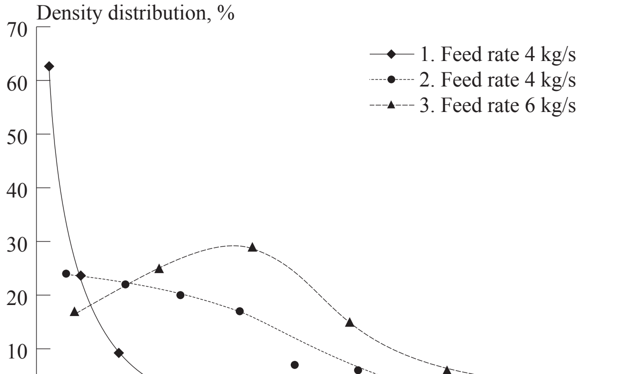


Fig. 7 Concave separation density distribution vs concave length



whole machine is very simple and compact. A recent testing record of new model VC2A threshing unit by Government Quality Appraisal and Inspection Center for Farm Machinery is shown below:

Table 3 Model VC2A machine testing results (wheat 2000, 6,14)

Testing item	NJ-code	Testing result
Impurities	< 2.00 %	0.47 %
Total loss	< 1.50 %	0.20 %
Cracking	< 0.70 %	0.05 %

The above testing data was obtained at max. feed rate 2 kg/s

It should be noted that the small total loss of 0.2 % was only air cleaning loss.

The model VC2A threshing unit had been used to design a prototype combine semi-mounted on the tractor to harvest wheat in the field test (**Fig. 1**). The tested field loss was 0.7 %.

It is, therefore, believed that, should the VAFT unit be commercialized to make a low-cost combine, the farmers in developing countries could use this harvesting machine to speed up their field mechanization.

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(Continued from page12)

Noise Levels in Indian Cotton Gins

permissible exposure limit. In the press house, the noise level ranged from 79.3 to 93.5 dBA for different models of presses. It was more than equal or above the permissible limit. The gin house was the noisiest workstation with an average noise level of 96.0 dBA. The noise level for the workstations such as raw cotton suction fan, pre-cleaner, gin house, central platform, seed blower and press operator room was above the permissible exposure limit. This calls for appropriate remedial measures such as proper size, design of the gin and press house, proper machine layout and locating the fans in separate rooms. Loud noise affects the overall efficiency, safety and hearing ability of the workers. Protecting the workers from loud noise by employing technical and personal measures of noise control could create healthful working conditions in gins.

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Storage Stability of Selected Agricultural Grains

by

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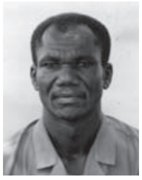

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Abstract

Three grains maize, sorghum and millet were stored at different levels of moisture contents 10 %, 20 %, 30 %, 40 %, 50 %, 60 %, 70 %, 80 %, 90 % and 98 % wet basis in order to determine the optimum moisture content for maximum grain stability. The effects of moisture content levels on their quality at three different temperatures levels (20 ºC, 25 ºC and 40 ºC) were evaluated. The Rockland (1969) concept of local isotherm was used to interpret the responses of the physical properties while the free energy equation was used to evaluate the energy levels of the grains at these moisture contents. This resulted in stability curves which showed that grains equilibrated by desorption (drying) have a two point minima levels (11.40 and 18.81 % at 20 ºC, 12.75 and 18.84 % at 25 ºC and 15.00 and 18.48 % at 40 ºC for maize; 11.46 and 18.92 % at 20 ºC, 11.36 and 18.92 % at 25 ºC and 12.29 and 18.62 % at 40 ºC for sorghum; 13.45 and 19.81 % at 20 ºC, 14.79 and 21.20 % at 25 ºC and 14.25 and 20.85 % at 40 ºC for millet) that gives rise to a wider safe moisture range than by adsorption (humidification). The results further revealed that the three grains showed optimum moisture for stability above and below which deterioration takes place rapidly.

Introduction

Moisture is an important and major constituent of all biological materials. It serves as a reactant, solvent and a vehicle for conveying other soluble constituents within the biomaterials. The control of moisture in storage and processing has been in practice for a long time. Moisture control measures such as salting, drying, sugaring and freezing is means of preserving food materials (Darby, 1976; Salaman, 1940; Tannahill, 1974) that dated back to early civilization period. These processes were adopted to control moisture availability with the ultimate aim of making biomaterials stable thus preventing physical degradation due to chemical and biological deterioration.

However, most of these control measures were not documented until late 1950's when Salwin (1957) and Scott (1957) came up with the concept of water activity (Aw), (defined as the ratio of vapour pressure of biomaterials to that of pure water at the same conditions). In those early days, maximum storage stability was associated with minimum moisture content. It was later demonstrated (Martnez and Labuza, 1968; Rockland, 1969) that a range of moisture contents exist below and above which food deterioration takes place rapidly. Thus the concept of defining minimum moisture content for food materials known as Local Isotherms (L.I.) was brought about. Rockland (1969), working on walnut, kernels reported on a safe range of moisture content and consequently divided moisture in biological products into three isotherm regions tagged local isotherms (L.I.) with differential stability coefficients. By this division, water activity (AW) below 0.138 was designated as L.I.1, AW between 0.138 and 0.264 was designated as L.I.2 while above this level is termed L.I.3. However, this range could only be a guide since biological materials vary widely in composition and cellular arrangement.

The objectives of the study reported in this paper were, (a) to evaluate the effects of moisture content and local isotherm regions on physical and physiological properties of grains and (b) the use of free energy concept to define optimum moisture content for maximum storage stability of grains.

Theoretical Background

The moisture content of any hygroscopic material, including agricultural products, is a function of the properties of both the material and its environment. The affinity for water by any biological material varies with the inherent initial moisture content, the product composition, the water affinity (hydrophillicity or hydrophobicity), and the moisture availability in its environment (environmental relative humidity) Ajisegiri (2000). These three factors together determine the hygroscopicity of any biomaterial. All the three factors are related to energy balance since free energy is responsible for the transfer of water molecule first to the vapour state, and from the vapour state into or away from the absorbing surface. The energy balance could, in turn, be related to a typical heterogeneous chemical reaction rate that is dominated by resistance to diffusion between phases in which every slight increase in reaction rate is accompanied by rise in temperature.

The free energy involved in water transfer was reported by Igbeka (1987) to be:

$$\Delta F = \frac{RT}{18} \ln\left[\frac{P_0}{P}\right] \quad (1)$$

Where, ΔF = Free energy change, R = gas constant, T = temperature, P_0 =vapour pressure of pure water, p = vapour pressure

This is free energy change during the transfer of 1 g of water in an isotherm process whose.

Integral is the form;

$$\Delta F = \frac{RT}{18} \int \frac{M}{RH} d(RH) \quad (2)$$

Where, M = moisture, RH = relative humidity

The equation forms the basis of the formation of "stability isotherm" which has been successfully applied to some crops with accurate results (Rockland, 1969). Equation (1) is also similar to the differential coefficient of moisture with respect to relative humidity whose integral could be written as;

$$\frac{\Delta M}{\Delta RH} = \int_0^{\infty} \frac{M}{RH} dM \quad (3)$$

Comparatively, Equation (2) is similar to (3), which is free energy change involved in a transfer of 1 g of water in an isothermal process expressed in terms of relative humidity (RH). In both equations, M is a function of relative humidity (RH) while in equation (2) RT/18 is a constant. Considering Equation (2) the integral function is minimised when M/RH is of minimum value. Consequently, free energy is also minimised at this point. That is the point where minimum slope occurs on the L.I. curve or where a minimum change occurs in M/RH with M. It could therefore be stated that maximum stability of biomaterial occurs at M/ERH coordinates where minimum change of moisture content takes place per change in equilibrium relative humidity. This concept was applied in this study to analyse the moisture data and to determine product stability of maize, sorghum and millet at 20 ºC, 25 ºC and 40 ºC respectively.

Experimentation

Maize, sorghum and millet, were obtained fresh from the National Cereals and Seed Service Federal Dept. of Agric. Ibadan, Nigeria with initial moisture content of 16.27 %, 16.01 % and 19.47 % (wet basis) for maize, sorghum and millet respectively. The grains were threshed by hand (to prevent mechanical damage) and dried to a moisture content of 4 % wet basis (4.2 % dry basis) to enable the determination of water

Table 1 Grain surface texture

Fresh	Region A (L.I.1)	Region B (L.I.2)	Region C (L.I.3)	Crop
Smooth surface, partially shiny	Smooth, partially shiny, shrunk grem, shrink appearance with powdery surface	Smooth, partially shiny with slightly shrunk grem appearance	Bloaty, cakey, black spots deposition on the surface (fungal growth)	Maize
Slightly rough	Slightly rough, sunken germ and protruded ends, partially shiny	Slightly rough surface	Brittle, round, shade bloaty appearance	Sorghum
Shiny, slippery and smooth	Shiny, slippery and smooth with brittle ends that easily break	Shiny, slippery and smooth	Dull looking, cakey with outer whitish deposit	Millet

Table 2 Grain colour variation

Fresh	L.I.1	L.I.2	L.I.3	Crop
Light to very deep yellow	Deep yellow	Light to deep yellow	Light yellow with black spots	Maize
Light to deep reddish brown	Very deep reddish brown	Light reddish brown	Very light red with whitish outer coat	Sorghum
Milky white	Light brown with deeper brown	Milky white with a shade of deep colour	Light colour with whitish deposits on outer surface	Millet

activity at a relative humidity range of between 10 % and 98 %. The low moisture content was achieved by slowly drying a bulk sample of the products in a laboratory vacuum oven at a temperature not exceeding 5 ºC. After drying, the grains were packed in sealed plastic bags and stored.

Ten grams (10 g) of each grain sample were placed in an equilibrium chamber containing saturated salt solution that develops known equilibrium relative humidity at specific temperature, as described by Greenspan (1977), Bosin and Easthouse (1970) and Igbeka et al. (1975) and modified by Ajisegiri and Igbeka (1986) and re-modified by Ajisegiri (1987). When the samples reached constant weight, equilibrium moisture content was determine by drying in an air oven for 12 hours at 103 ºC (± 2 ºC).

The equilibration time varied between forty-eight and ninety-eight hours but the experiments were continued after these periods for 1680 hours (about 10 weeks) to monitor physical changes such as weight gain/loss and germination and proliferation of microbiological organisms. The germination or viability tests were conducted by planting some seeds from both the fresh and the treated samples. Four (4) replicates of equilibrium moisture content (e.m.c.) at the set temperatures and relative humidity (rh) were carried out and the mean values were used for each plot.

The temperatures 20 ºC, 25 ºC and 40 ºC were obtained by submerging the experiment chamber in thermostatically controlled water in a bath, with an accuracy of ± 0.5 ºC. A total of 299 samples were used for the experiment. The temperature ranges used represented the average prevailing storage temperature variation in the tropics throughout the year. For the interpretation of the local isotherm, the equilibrium relative humidity (e.r.h.) range was divided into three parts:

i. A monolayer region (Region A) or local isotherm one (L.I.1) which ranges between 0-20 % e.r.h.
ii. A multilayer region (Region B) or local isotherm two (L.I.2) which ranges from 20-70 % e.r.h.
iii. Capillary condensation region (Region C) or local isotherm three (L.I.3), which ranges between 70-98 % e.r.h. (Labuza et al., 1970).

Results and Discussion

Results

The results of the visual inspection and textural evaluation carried out on the fresh and treated samples are shown in **Tables 1** and **2**. Results on germination tests and shape variation are presented in **Tables 3** and **4**. The sorption data obtained was used to compute variation in moisture content at each e.r.h. level at various temperatures and presented as stability curves, **Figs. 1** to **6**.

Table 3 Grain germination variation, %

Fresh	L.I.1	L.I.2	L.I.3	Crop
90	45	88	0	Maize
80	82	85	0	Sorghum
90	0	90	0	Millet

Table 4a Average grain shape variation for maize

	Major diameter	Minor diameter	Thickness	Projected area	Circular area	Sphericity
Fresh	10.894	8.695	5.100	70.313	84.102	0.863
SD	0.77	1.530	0.917	11.128	21.532	0.084
Region A (L.I.1)	10.351	8.508	4.663	69.989	86.287	0.841
SD	1.648	0.871	0.827	17.668	25.316	0.151
Region B (L.I.2)	10.892	8.703	5.062	70.293	84.293	0.865
SD	1.77	1.138	1.407	12.802	12.802	0.220
Region C (L.I.3)	10.961	8.760	4.525	72.103	89.167	0.872
SD	0.713	0.778	0.468	14.811	17.860	0.044

Table 4b Average grain shape variation for sorghum

	Major diameter	Minor diameter	Thickness	Projected area	Circular area	Sphericity
Fresh	4.563	3.998	2.662	16.620	16.400	0.883
SD	0.462	0.216	0.187	1.680	1.510	0.041
Region A (L.I.1)	4.374	3.968	2.617	15.212	15.126	0.847
SD	0.354	0.346	0.257	3.108	2.457	0.091
Region B (L.I.2)	4.584	4.029	2.684	16.613	16.399	0.884
SD	0.234	0.197	0.260	1.732	1.519	0.039
Region C (L.I.3)	4.585	4.216	2.788	16.982	16.466	0.920
SD	0.296	0.273	0.251	2.098	2.095	0.040

Table 4c Average grain shape variation for millet

	Major diameter	Minor diameter	Thickness	Projected area	Circular area	Sphericity
Fresh	3.082	2.502	1.719	6.820	8.028	0.826
SD	0.136	0.924	0.567	2.338	1.364	0.207
Region A (L.I.1)	3.006	2.368	1.751	6.727	7.128	0.792
SD	0.196	0.143	0.142	0.618	0.922	0.088
Region B (L.I.2)	3.067	2.492	1.772	6.809	7.989	0.824
SD	0.151	0.056	0.059	0.933	1.380	0.108
Region C (L.I.3)	3.271	2.569	1.852	7.123	8.477	0.843
SD	0.319	0.179	0.119	0.688	0.568	0.060

SD = Standard deviation

Discussion

Observations show that the physical conditions of grains kept under ambient condition exhibits similar properties as those stored under local isotherm 2. This indicates that although variations do occur in temperature and equilibrium moisture contents of these grains stored at ambient condition, the variation oscillate around the simulated conditions under local isotherm 2. Consequently, the colour, texture, physical dimensions as well as the germination rates under these conditions are similar.

Under a very low relative humidity typified by local isotherm one, the colour takes a deeper shade. The grain texture also is more rough and brittle and there is a physical appearance of elongation although under this same condition, maize looses about 50 % of its germination capacity. The physical dimensions generally tend to shrink under this condition. There is a marked reduction in both the major and minor diameters, the thickness and the projected areas of the grains as well as the sphericity.

Plots of (m/r h) versus (m) for maize, sorghum and millet at various temperatures were used to establish the stability curve of the grains. These curves (**Figs. 1** to **6**) showed a definite pattern of moisture content for optimum storage stability of grains.

The curves showed that there exists a range of moisture contents where the stored grains are most stable. Using the sorption curves, the stability range could be obtained. This is shown in **Table 5**.

This range denotes the moisture content region where least physical property change per unit change in relative humidity occurred. This is vital information for storage purposes. It is difficult to keep moisture content of stored grain constant under natural storage condition. Therefore, the range indicates the safe moisture content within which grains could be stored and the time for drying, aeration or humidification if the natural moisture condition fluctuates beyond the safe limits.

It is also interesting to note that the range for all the grains fall within the L.I.2, which conforms to the

Fig. 1 Adsorption moisture stability curve for maize

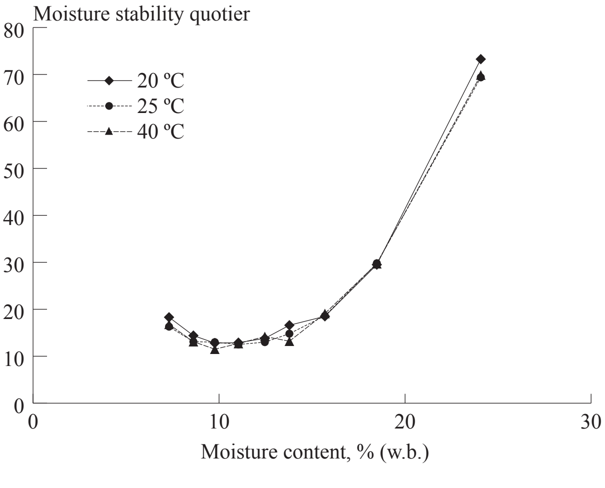


Fig. 2 Desorption moisture stability curve for maize

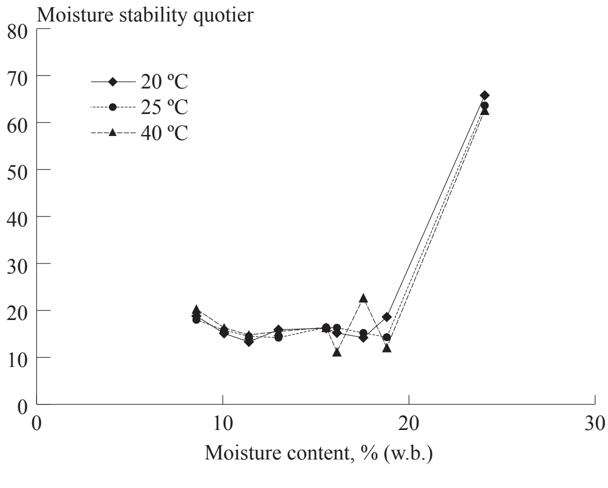


Fig. 3 Adsorption moisture stability curve for sorghum

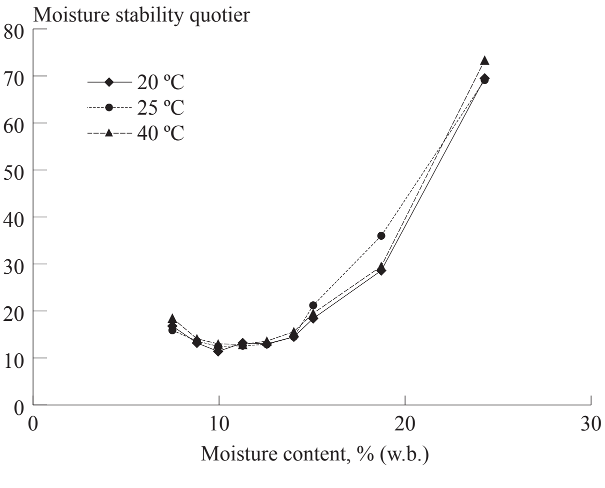
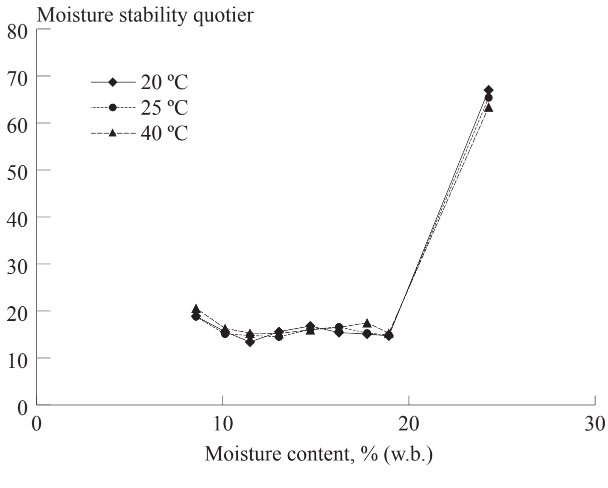


Fig. 4 Desorption moisture stability curve for sorghum



prediction of Rockland (1969). The desorption data range does not only falls within the L.I.2 but it is wider and similar in pattern to the theoretical stability model proposed by Rockland and Nishi (1980). Stability curves from adsorption data exhibited two maximum values (6.90 and 23.93 % at 25 ºC, 5.90 and 23.49 % at 40 ºC for maize; 7.08 and 24.13 % at 25 ºC, 6.00 and 23.69 % at 40 ºC for sorghum; 9.38 and 26.43 % at 25 ºC, 8.29 and 26.00 % at 40 ºC for millet) and one minimum value (10.76 % at 25 ºC, 8.50 % at 40 ºC for maize; 9.68 % at 25 ºC, 10.00 % at 40 ºC for sorghum; 11.99 % at 25 ºC, 12.28 % at 40 ºC for millet) at 25 ºC and 40 ºC. At 20 ºC however two minimum levels (9.77 and 13.78 % for maize; 9.95 and 12.57 % for sorghum and 12.24 and 13.35 % for millet) were also recorded. This is an indication of the effect a reduced temperature has on stored produce.

Desorption data on the other hand produced at least two minimum values in all cases and at all temperature levels. They were for maize, 11.40 and 18.81 % at 20 ºC, 12.75 and 18.84 %, at 25 ºC, 15.00 and 18.48 % at 40 ºC; for sorghum, 11.46 and 18.92 % at 20 ºC, 11.36 and 18.92 % at 25 ºC, 12.29 and 18.62 % at 40 ºC; and for millet 13.45 and 19.81 % at 20 ºC, 14.79 and 21.20 % at 25 ºC, 14.25 and 20.55 % at 40 ºC. From this observation, it is possible to propose extending the range of storage temperature coverage of the experiment, Desorption curves in grains might produce a sinusoidal curve, which would probably be negatively skewed towards the capillary condensation region. The implication is that the higher minima values of the curves could be the moisture content points at which the grains are relatively stable, in other words meta-stable points, outside of which grains are expected to degenerate fast.

Furthermore, the stability curves seem to suggest that for grains intended for storage, it is better if equilibrium moisture content is attained through the desorption path. This is because of the longer range of moisture where grains are expected to be stable on this path. This also is in agreement with the recorded values of hysteretic volume, isosteric heat and entropy change in grains that showed less change in values at the desorption path than at the adsorption path (Ajisegiri, 1987).

It therefore means that the stability of grains during storage is a function of relative humidity, the path of equilibrium moisture content, temperature and the type of crop. These factors determine the respiratory rate, reaction kinetics, the enzymatic and non-enzymatic reactions, lipid and auto-oxidation as well as the microbiological activities.

Conclusions

From this study and other supporting literature, it was concluded that there exist an optimum moisture content at which stability of grains is maximum. This optimum value is temperature dependent. For grains intended to be stored under normal air storage methods, the longest range of moisture tolerance is attained when grain is dried to the storage moisture and not through humidification.

Table 5 Optimum storage moisture (% w.b.) for grains at 20, 25 and 40 ºC

Crop / Temp	Sorption			Desorption		
	20 ºC	25 ºC	40 ºC	20 ºC	25 ºC	40 ºC
Maize	9.77	10.76	8.50	11.40-18.81	12.72-18.38	15.00-17.63
Sorghum	12.57	9.68	10.00	11.46-18.92	12.81-18.90	12.29-18.62
Millet	12.24	11.99	12.28	13.45-19.81	14.79-21.20	14.25-29.85

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Fig. 5 Adsorption moisture stability curve for millet

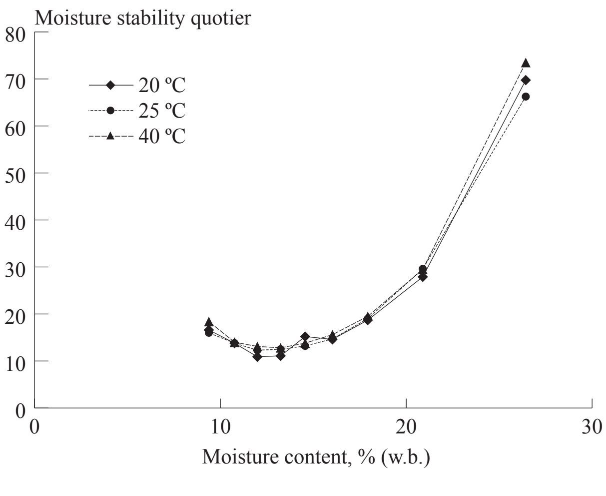
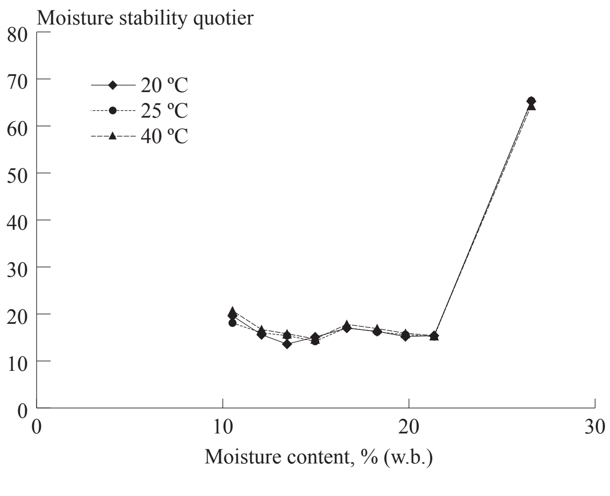


Fig. 6 Desorption moisture stability curve for millet



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Design of Tool Carrier for Tillage Studies of Disc in Field Conditions

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Abstract

A special disc carrier for mounting a single disc was designed and fabricated which served as a key component of the test set up to study the effect of disc geometry and forward speed on draft and soil throw. The tool carrier was suitable to mount different geometry discs and change operational parameters. An experiment on performance evaluation of discs with varying geometry was done for determination of draft requirement and soil handling capability. Disc concavity showed pronounced effect on draft and soil throw. Information may provide the guidelines for manufacturers and farmers in selecting optimum disc parameters for desired soil manipulations. Information may also be useful for different organizations working in the field of farm mechanization including institutes standardization of the disc parameters.

Introduction

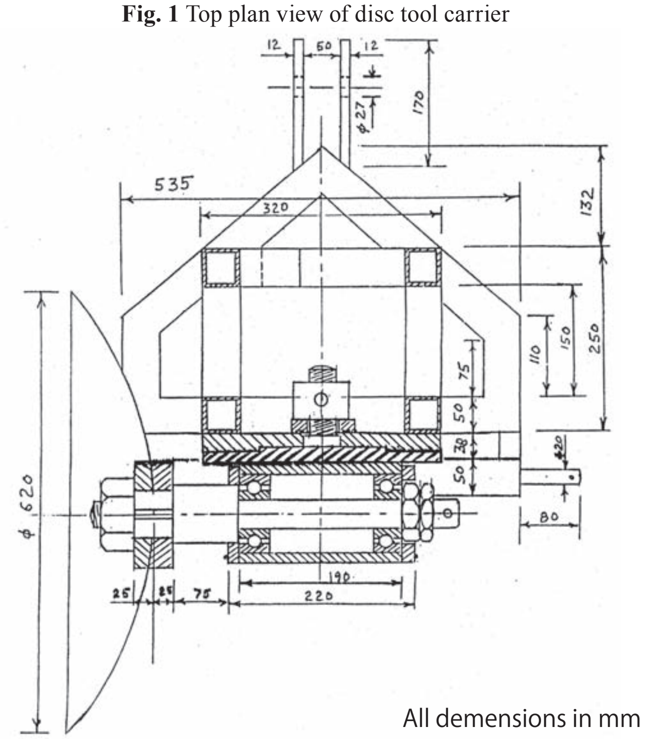
Both soil cover conditions and soil physical characteristics such as structure and texture demand different macro-shapes of soil working tools as well as operating conditions. Different crops require different seedbed conditions for given cropping situation. Hence, the soil-tool-tillage combination should be studied for a given location and tool geometry to optimize the tool performance and energy efficiency. A tillage tool, particularly the disc system, must reduce clods to the desired degree and manipulate the soil sufficiently. Energy applied to the soil by the disc must be utilized efficiently in breaking up the soil. The power requirement per unit of soil tilled must be low. The capacity of the disc system must be high. Thus, evaluation of performance of the disc-soil system requires measurement of soil conditions to determine when and how much a condition is changed by a manipulation, and an understanding of the interaction between disc and soil that would allow the prediction of disc performance from known soil and disc parameters. A disc could then be set, for example, to operate in a particular soil at a predetermined depth or with minimum draft force. An evaluation of the physical disturbance imposed on the soil by a disc could provide the first step towards a solution to this problem. The mathematical description of tool geometry may determine how the design parameter influences the energy requirement and quality of operation. The important disc parameters are disc size and disc concavity. Soil parameters used to determine the performance of tillage discs are soil throw, soil volume disturbed, depth of penetration and final soil condition. The diameter of the circle formed by the disc edge relate directly to the geometry of the disc, whereas, the disc angle and depth of penetration define the altitude and position of the disc within the soil mass. The volume of soil swept out by the disc has been related to these parameters. Disc geometry dictates both energy requirement and final soil condition. Soil physical parameters are very variable in field conditions. Results of study in controlled condition may not be applicable in field conditions. To avoid this it was thought prudent to design a tool carrier which facilitates testing of a single disc tool in the field. The scope of this paper is the design a tool carrier for mounting of a disc to facilitate change of different size discs along with operational parameters. The study also aims to obtain information on disc size and concavity required for the desired degree of soil manipulation through soil cut. The requirement of draft in accomplishing the above tasks was also determined.

Materials and Methods

Disc Carrier

A special experimental set-up primarily consisting of a tool carrier suitable for mounting discs of different sizes was designed and fabricated. Since the experiment required test evaluation of a single disc, the stability of the disc system was a major challenge. The overall size of thetool carrier was 68 x 71 x 60 cm with a weight of 107 kg excluding the weight of the disc. The main frame was made of hollow square of mild steel having a section of 50 x 50 x 6 mm. The disc was mounted on a shaft with a diameter of 5 centimeters. The discs, as supplied by the manufacturer, had a central hole of different shape and size. These holes were machined and converted into round shape. The discs were fitted to the shaft with the help of keys. A heavy duty nut was also used to tighten the disc to the disc carrier. The tool carrier included an arrangement to change the disc position by changing the disc angle (**Fig. 1**). The different positions of the disc could be attained with the help of a rotating circular plate having holes for fixing the disc with the help of heavy duty pin. The shaft was mounted on a bearing housing to make its movement free with minimum resistance. The disc carrier facilitated change of different size discs with varying concavity, depth of operation and disc angle. Mounting and demounting of disc and operation was simplified by proper design (**Fig. 2**).

Fig. 1 Top plan view of disc tool carrier



Disc

Discs of different diameter and concavity were procured to study the influence disc geometry on draft, soil throw and average soil volume disturbed. The specification of the disc are given in **Table 1**.

Field Experiments

The main objective of the field test was evaluation of different geometry discs for its effectiveness in performing the intended job and efficiency in energy utilization. The depth of operation was controlled by the top link of the three-point linkage system which was hydraulically operated. A hydraulic dynamometer was used as the connecting link between the two tractors for measuring

Fig. 2 Changing of disc - an easy process

the draft. Tests were conducted in two different soil cover conditions, namely unploughed and ploughed. These represented the soil conditions requiring the use of all or one of the test implement for seed bed preparation. The field was irrigated and allowed to dry to attain desired moisture levels. Two tractors were used to measure the draft of the disc system. A 35 horsepower tractor was used as driving unit for the dummy tractor, hitched in tandem and mounted with the implement under test. The dummy tractor was a 55 hp (HMT 5911) tractor to which disc system was attached with the help of three point linkage. The data were related to energy consumption (draft and speed) along with time and soil conditions before and after the operation of the disc. Indicators of effectiveness of tillage operations were soil throw, soil volume disturbed. Observations were made on motion resistance of the dummy tractor and single disc system, soil throw, furrow cross-sectional area, speed of operation and soil moisture content. Three replications were made for each test of the disc system in a given soil condition. Disc angle was not changed. Depth and width of cut were guided by disc size and concavity, and a range of depth and width was maintained and measured. All other observations like soil throw, depth and width of cut and time consumed to cover a 20 m strip were collected for each disc set-up at all the three speeds. Similar data were collected for all the discs at different speeds when the set-up was operated in the second soil cover condition.

Results and Discussion

Disc Geometry and Draft Requirement

Disc diameter and concavity influenced draft requirement. The highest draft was required by disc D9 in unploughed condition. Overall the draft ranged between 147.33 kg and 226.66 kg (**Table 2**). In general, larger diameter required higher draft. However, disc concavity for a given diameter and concavity interacted well to influence draft requirement. The increase in draft was caused by greater depth of penetration and larger soil volume disturbed.

Table 1 Specifications of discs used in the study

Disc	Diameter, mm	Concavity, mm	Thickness, mm	Disc weight, kg
D1	510	51	3.5	8.3
D2	510	57	4.5	8.5
D3	510	68	4.0	9.0
D4	560	64	6.0	14.0
D5	560	70	4.0	10.0
D6	560	78	4.0	10.5
D7	610	76	4.0	17.0
D8	610	83	6.0	11.5
D9	610	95	4.0	12.0

Table 2 Disc and tillage performance

Disc	Disc diameter/ concavity	Draft, kg		Soil throw, cm		Soil disturbed, m^3/min
		Ploughed land	Unploughed land	Ploughed land	Unploughed land	
D1	10.0	147.33	177.00	70.6	63.53	2.66
D2	8.9	155.66	187.66	74.3	66.9	2.68
D3	7.5	160.66	193.00	78.6	70.76	2.80
D4	8.8	151.33	181.66	74.63	67.3	2.90
D5	8.0	164.33	197.33	79.6	71.66	3.15
D6	7.2	169.33	203.33	83.3	74.93	3.07
D7	8.0	146.00	175.66	77.2	69.5	3.66
D8	7.3	175.66	211.00	89.56	80.63	3.71
D9	6.4	189.00	226.66	91.53	82.4	3.80

Disc and Tillage Performance

Two parameters of disc geometry (radius of curvature and disc concavity) play a very important role in soil handling, soil rapture, inversion and creating more soil mass in front of the disc. All these factors, demand more energy but help in getting desired soil tilth. For a disc diameter of 510 mm and three concavity levels of 51, 57 and 68 mm, the soil throws were observed as 70.6, 74.3 and 78.6 cm, respectively in the ploughed condition. Similarly, in case of 560 mm diameter, for three concavity levels of 64, 72 and 78 mm, the soil throws were recorded as 74.8 cm, 79.6 cm and 83.3 cm under ploughed conditions. The largest throw of 915 mm was recorded in case of disc diameter of 610 mm with a concavity level of 95.53 cm. (**Table 2**). It could be observed that the influence of larger disc size could be offset by smaller concavity in moving soil mass a certain distance. For example, in ploughed land a 510 mm diameter disc with 57 mm concavity gave similar performance to 560 mm diameter with 64 mm concavity.

Field Cover Conditions

Field cover also influenced draft and soil throw by individual discs. A maximum of 34 kg difference in draft and 9 cm in soil throw was observed in ploughed and unploughed condition (**Table 2**). The unploughed cover condition required higher draft and recovered less soil throw.

Diameter to Concavity Ratio

Diameter to concavity ratio for selected discs varied between 6.4 and 10.0 during the experiments.

In general, the larger this ratio the less the draft requirement and the less was the soil throw. Among the discs with constant diameter but varying concavity, the influence of this ratio was prominent. The values of this ratio for largest soil throw in different diameter categories were observed as 7.5, 7.2 and 6.4 (**Table 2**). The larger the ratio of diameter to concavity better the soil throw but the higher the draft, Thickness of discs also varied but its influence was not pronounced. The geometry influences vertical force and the vertical force represents the load required for penetration to the cutting depth so that it is possible to construct lightweight harrows to operate at the desired depths. The reduction in draft force allows a given size of tractor to pull harrows of increased size or at an increased speed. An important design consideration is the variable nature of changes in the magnitude and direction of side forces acting on discs, which is dependent upon radius of curvature and disc angle. The best discs were among those having disc diameter to concavity ratio between 7.5 to 6.4. This result may provide the guidelines for manufacturers and farmers in selecting optimum disc parameters for desired soil manipulations. This information may also be useful for different organizations working in the field of farm mechanization including institutes of standards for standardizing the disc parameters.

Conclusions

1. The tool carrier permitted change in disc size and operational parameters for tillage studies.
2. The disc diameter, concavity and forward speed interacted well and influenced draft positively.
3. Soil throw was greatly influenced by disc concavity. For an increase of 44 mm in concavity of disc in diameter range of 510-610 mm an increase of 30 per cent was noticed but this effect was mainly due to increased concavity.
4. Soil throw values for ploughed condition were higher than that for unploughed condition. The draft showed an opposite trend.
5. The best diameter to disc ratio ranged from 7.5 to 6.4.
6. The information may provide guidelines for selection of proper geometry of a disc for given field conditions.

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Design, Development and Evaluation of Seed Cum Fertilizer Drill

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Abstract

A study was conducted on design parameters of various seed, soil and machine components of a seed cum fetilizer drill. Based on the information generated, a 3 row animal operated seed cum fertilizer drill was developed and evaluated. The replicated tests revealed that germination of paddy wheat, gram, soybean and linseed was not affected by the gravity flow orifice type metering mechanism. The average draft and field capacity of the seed drill were 54 kgf and 0.10 ha/h respectively. On demand of farmers, 100 units of seed drill were supplied during the year 2001-02 to the farmers of Chhattisgarh State.

Introduction

Two methods of cultivation of paddy are in practice in Chhattisgarh State of India, is namely broadcast Biasi and transplanting. About 80 percent of rice area is under traditional broadcast Biasi system of cultivation. In the traditional method the paddy seeds are broadcast with the commencement of monsoon, and when there is an accumulation of 10-15 cm of water, the 4-6 weeks old standing crop is ploughed by country plough followed by manual weeding and gap filling. This practice is called Biasi. The Biasi is usually delayed due to erratic distribution of rainfall and frequent dry spells causing increased weed population, poor plant growth and sub-sequentially drastic reduction in yield. To overcome the inherent defects of broadcast Biasi, line sowing technology was recently introduced in this state. Line sowing is the most efficient means of sowing the crops and most ideal for crop management (Devnani, 1989). It facilitates manual and mechanical weeding between rows, optimum plant population, even with reduced seed rate, lower and more efficient seeding rate than broadcasting. Row seeding also promotes maximum tillering and better sunlight penetration.

Chhattisgarh is a tribal populated state. Tribals are just living at the subsistence level. The adaptability of row sowing technology for paddy and other crop areas is very limited and restricted up to certain areas only because of non-availability of quality sowing implements. All kharif crops are sown by broadcast method and present serious problems of weed infestation. (Shukla, 1989). Because of the demand it was decided to design and fabricate a seed cum fertilizer drill that was low cost and easy to operate by the non-skilled/average worker. The seed drill could be used for a wide range of crops as well as soil and climatic conditions of Chhattisgarh. In view of the above, a seed cum fertilizer drill was developed in the Faculty of Agril. Engg. IGAU. Raipur for sowing of paddy, wheat, soybean, gram and linseed crop.

Materials and Methods

The three major factors viz. seed, soil and machine, which affect the performance of seed drills, were taken in consideration.

Seed

The quality of seed and their viability are the most important factors, which affect final germination. Therefore, germination tests were performed in the laboratory on seed samples before sowing them in to the field. The seed drill was designed to meter the seed based on seed rate recommended in terms of weight per unit area. Physical characteristics of seeds, which were taken for study, are given in **Table 1**.

Soil

Quite a diverse type of soils occurs in Chhattisgarh. Differing widely in their characteristics locally called Bhata (Entisols), Matasi (Inceptisols and Alfisols), Dorsa (Verti Alfisols) and Kanhar (Vertisol). Chhattisgarh State receives sufficient rainfall (1,100-1,600 mm) but its distribution is erratic. The monsoon season extends from late June to early October accounts for over 95 % of the annual rainfall. Two thirds of the precipitation occurs only in the month of July and August. Therefore, farmers always face either deficiency or excess moisture. The time available for friable soil condition that is suitable for tillage and sowing operation is always very short. Another problem which affects the tillage and sowing operation is the presence of iron oxide in the soil. Due to presence of iron oxide, soil becomes very sticky when moisture content is more than 18 % and very hard when soil moisture is less than 5 percent. Physical properties of important soil types are given in **Table 2**.

Machine

Design of Seed Cum Fertilizer Box

The seed cum fertilizer box was made of hot rolled 14-G thick sheet. The cross section of the box was trapezoidal. The bottom of seed box was flat. The inclined guiding plates were fitted at the base to help movement of seed towards the inlet opening of metering devices. The seed cum fertilizer box was located above the main frame supporting the furrow opener and transport cum depth control beam. A partition was provided along the length of box. The size of fertilizer box was 10 % larger because higher rates of fertilizer were applied as compare to seed. The location of the seed cum fertilizer box was 650 cm above the ground. This height of box helps to reduce the angle of inclination of seed delivery tubes.

Box capacity in terms of volume Vs in m^3.

$Vs = Q_S/\rho$ ....(1)

$Vs = A \bullet L$ ....(2)

$A = Q_S/\rho \bullet L$ ....(3)

Where

A: area of cross section in m^2,

L: length of box in m and

Q_S: box capacity in kg.

The length of the box was

$L = nd - 2b$, ...(4)

Where

n: number of furrow openers,

d: distance between two furrows in m,

b: distance between side wall of the box from the wheel and the value of b was

b = 0.1 m.

To compromise with pulling capacity of medium and small size bullock and cost of seed drill, the length of box was made such that the delivery tube would convey the seed and fertilizer smoothly. For the 3-row seed drill, if row to row spacing was kept 0.2 m, the length of box was 0.4 m.

Table 1 Physical characteristics of seeds

Name of seed	Axial dimension, mm			Moisture content, %wb	Unit weight of seed, g	Bulk density, kg/m^3	Sphericity %
	Length	Width	Thickness				
Paddy	9.11	2.95	2.14	10.5	0.0323	646	39.42
Wheat	6.33	3.26	2.78	10.9	0.0458	768	61.50
Gram	7.56	5.27	5.27	11.6	0.1546	911	78.22
Soybean	6.77	4.80	4.80	11.0	0.1064	719	83.31
Linseed	4.76	1.31	1.31	11.4	0.0075	696	51.58

Table 2 Physical properties of important soil in Chhattisgarh region

Property	Soil type			
	Bhata	Matasi	Dorsa	Kanhar
Colour	Red	Yellow	Brown	Dark brown/black
Soil depth, cm	5-20	20-75	75-125	Greater than 100
Mechanical composition, %				
Sand	65.2	42.4	21.5	19.0
Slit	24.2	35.6	46.2	32.8
Clay	19.6	22.0	32.7	48.2
Texture	Sandy-loam	Loam	Sity clay loam	Clay
Bulk density, g/cm^3	1.5-1	1.5-1.6	1.4-1.6	1.3-1.4
Plastic limit				
Upper, depth (10-30 cm)	33.00	39.33	43.33	56.33
Lower, depth (0-20 cm)	21.00	21.00	24.66	35.66
Infiltration rate, cm/h				
July	0.82	0.20	0.25	0.86
October	0.86	0.65	0.87	1.50

The area of cross section of the seed cum fertilizer box was determined by

$A = h (B + h \cot\alpha)$ ....(5)

$\alpha = 75^o$

$h = 0.21$ m

$B = 0.30$ m

$A = 0.06$ m^2

Recommended seed rates, row spacing, and other important seed machine parameters for design of seed drill are given in **Table 3**.

Seed Metering Mechanism

While designing the seed metering mechanism, prime consideration was given to use less sophisticated line-sowing technology, lower cost and easy fabrication by a local workshop. Therefore, a stationary orifice with agitator type metering mechanism devices was selected to meter the seed. The orifice plate has a set of holes according to the size of seed and seed rate. A ribbed rubber type agitator was provided just above the orifice that prevented the blockage of the orifice. The physical properties of seed, the size and shape of orifice and geometry and dimension of seed box affected flow rates of seed.

The flow rates of seed from the orifice, given by Bernacki (1972), is expressed by

$Q = F \cdot \rho_l \cdot A_0 (2g \times P/\rho_l)^{0.5}$, ...(6)

Where

Q = Flow rate of grain,

F = Flow rate index to be determined from measurements,

ρ_l = Bulk density of materials as it pours out of orifice,

A_0 = Flow areas of orifice,

g = Acceleration due to gravity and

P = Static pressure produced by seed mass.

The value P is expressed as

$P = d_l \rho_l / \gamma \tan\phi$ ....(7)

Where

ϕ = Angle of internal friction of material,

$\gamma = \tan^2 (45^o - \phi/2)$,

$d_l = d - d'$ and

d is diameter of orifice and d' reduction in d due to flow.

$Q = F \cdot \rho_l \pi (d - d')^{2.5} [g/8 \tan^2 (45^o - \phi/2) \tan\phi]^{0.5}$ ....(8)

The fertilizer-metering device used in the drill was an adjustable orifice type. In the bottom of the box a diamond shape hole was

Table 3 Seed and machine parameters

Crop	Seed rate, kg/ha	Row to row spacing, cm	Depth of sowing, cm	Funnelling angle of repose, º	Static coefficient of friction	
					Self grain	Steel and grain
Paddy	60-70	20	2-3	34º 2'	0.73	0.46
Wheat	80-90	20	3-5	30º 4'	0.58	0.41
Gram	60-70	20	5-8	39º 5'	0.66	0.45
Soybean	80-100	20	2-3	32º 2'	0.54	0.37
Linseed	30-35	20	3-4	29º 1'	0.51	0.39

Table 4 Specification of seed drill

Components	Specification	Material
Main Frame	Length: 850 mm	MS angle 35 x 35 x 5
Furrow opener	Shoe type, Double boot type 3 no., Adjustable Row to row spacing: 200 mm	Medium carbon steel Heat treated
Ground wheel	Rim dia: 320 mm, Rim width: 40 mm	MS flat, 40 x 5
Drive wheel	Number of lugs: 12, Lugs spacing: 30º, Lugs dimension 50 x 25 mm	MS flat, 25 x 3 mm
Metering mechanism Agitator Fertilizer metering	Orifice plate 160 x 150 mm, Set of holes dia (mm) 6, 10, 12 Ribbed 50 mm dia, 3 mm above orifice Orifice plate 150 x 150 mm, Set of diamond shaped hole 5, 8 mm	HR seet 14 G Rubber HR seet 12 G
Provision for seed and fertilizer cut off	Disengaging drive wheel leaver or sliding plate provided with spring loaded, Sliding plate 68 x 160 mm with 3 holes of 18 mm	MS flat 32 x 5 mm HR seet 14 G
Seed cum fertilizer box	Trapezoidal shape cross section, Upper side 380 x 310 mm, Bottom side 300 x 310 mm, Height 210 mm, Length: 500 mm 3 no each for seed and fertilizer, 25 mm outer dia, 2 mm thick	HR sheet 18G Polyethylene tube

Table 5 Mechanical damage to seed during metering and inter row variation of seed

Crop	Visual damage, %		Germination rate, %		Desired discharge per furrow for 20 revolution	Observed discharge per furrow opener 20 revolution		
	Unmetered seed	Metered seed	Unmetered seed	Metered seed		I Fur row	II Fur row	III Fur row
Paddy	0.7	1.4	94.4	94.1	36.95	38.1	37.1	39.6
Wheat	0.3	1.2	97.2	96.4	41.6	43.0	42.5	41.8
Gram	0.6	0.8	95.3	94.9	32.35	35.7	36.4	37.0
Soybean	2.96	4.85	86.6	84.3	46.22	45.3	44.0	45.2
Linseed	1.02	1.41	92.0	91.7	16.22	16.9	18.0	18.3

Data given are mean value of 5 observations provided below the box and a lever was provided for sliding this plate. Meshing the holes regulated the quantity of fertilizer. A star type agitator was provided to avoid the bridging of fertilizer.

Seed Delivery Tube

Polyethylene tubes of 25 mm diameter and 2 mm thick were used to convey seed from orifice to furrow opener by gravity.

Furrow Opener

Furrow openers were of shoe type made of medium carbon steel with a 25 mm square cross section. The rake angle was 28º in order to make a slit in the soil of 3 to 5 cm. The relief angle of the blade was 8º. The working edge was sharpened and heat treated to reduce wear. A double boot type of furrow opener was used for a dispersed band seed and fertilizer placement.

Frame

The frame of the 3-tyne seed drill was made of MS angle of 35 x 35 x 5 mm with a square cross section. The size of frame was 850 mm. Provision was made to adjust the spacing between two furrow openers.

Power Transmission Unit

The power required to operate the seed and fertilizer metering device was transmitted from the drive wheel. A counter shaft drive was provided so that power from one shaft could be transmitted to metering units since power transmitted to drive the sprocket of the metering unit was low. Motorcycle roller chains of 12.52 mm pitch were used. In the chain and sprocket drive, a lever was provided to lift the drive wheel from ground to disengage the drive wheel.

Depth Control

Support wheels were lifted or lowered by two bolts provided on the each end of the main frame to control the depth.

Evaluation of the Prototype

A 3 row prototype seed drill was assembled. The component parts were seed cum fertilizer box, metering unit, furrow openers, ground wheels and drive wheel. The components were mounted on a basic frame (**Fig. 1**) with the specifications as given in **Table 4**.

The seed drill was evaluated as per BIS6316-1971 standard for its performance during the year 2000-01, and 2001-02. Demonstration of the drill was carried out at farmer's field at 20 locations in the year 2001-02. Due to the introduction of line sowing technology in Chhattisgarh and demand of farmers, 100 seed drill units have been supplied to the farmers of this state.

Measurement of Different Parameter

The seed drill was laboratory tested for mechanical damage to seed during metering and for inter row variation and seed rate. An average size bullock was used to operate the seed drill. Observations were recorded on time taken to cover the area, actual depth of seed placement, seed rate and pull requirement. The soil related parameter like moisture content and bulk density was determined by standard procedure.

Table 6 Effect of level of seed hopper on seed rate

Crop	Desired seed rate, kg/ha	Desired seed discharge in 20 revolution	Level of seed in hopper			
			Full	3/4 th	Half	1/4 th
Paddy	80	110.8	113.2	110.9	122.8	134.7
Wheat	90	124.4	122.5	127.8	125.4	138.6
Gram	70	97.5	100.5	104.5	106.8	112.4
Soybean	100	138.7	129.72	138.0	140.7	142.1
Linseed	35	48.6	52.67	54.8	56.9	61.4

Data given are mean value of 5 observations

Table 7 Field performance of seed drill

Details type of soil	Year 2000-01		Year 2001-02	
	Loam	Silty clay loam	Loam	Silty clay loam
Soil moisture content, %	14.59	12.80	12.02	14.01
Cone index (kgf/cm^2) at 10 cm depth	5.68	7.85	6.62	7.14
Depth of sowing, cm	3.2	3.1	3.4	3.1
Width of sowing, cm	7.7	6.9	7.5	7.4
Draft, kgf	52.9	55.4	53.8	57.6
Effectives field capacity, ha/h	0.1047	0.1008	0.1064	0.1082
Plant population, no. of plant/m^2	178	191	179	183
Field efficiency, %	61.3	63.9	64.7	65.8
Clod mean weight diameter, mm	30.6	34.9	28.7	40.2
Seed rate, kg/ha	88	85	84	87

Results and Discussion

Laboratory calibration tests for mechanical damage to seed during metering and inter row variation in

Fig. 1 Design and developed Indira seed cum fertilizer drill

seed rate are presented in **Table 5**. During the laboratory test clearance between orifice and agitator was kept at 3 mm.

Mechanical damage of metered seed for paddy, wheat, gram and linseed were with in the range of 0 to 1 % and was 1-2 % for soybean The variations in germination values were within 1 %. The maximum variation of seed rate from the average among the rows and within the rows was 4 to 8 %

Effect of Seed Level on Seedrate

The effect of the level of seed in the hopper on seed rate was studied. When the level was up to half, there was no variation in required and observed seed rate. About 16-24 % variation was observed between 1/2 to 1/4 seed level in hopper (**Table 6**).

Field Performance Test

The field performance data are given in **Table 7**.

The field performance data (**Table 7**) indicated a similar trend to that observed in laboratory investigation. However, 8-10 % increase in seed rate was noticed that might be due to vibrations from rough ground conditions. The field capacity at an average speed of 2.45 km/h was 0.1050 ha/h with 64 % field efficiency. Thus on an average 0.8 to 1.0 ha/d area can be sown by a pair of bullock. An average plant population of 183/m^2 was obtained at seed rate of 87 kg/ha. The draft of implement varied from 51 to 56 kgf and speed from 2.35 km/h to 2.45 km/h. The power utilized varied from 0.44 to 0.50 hp.

Conclusion

Based on results of the experiment conducted during the year 2000-01 and 2001-02 the following conclusions could be drawn.

1. The test results indicated a satisfactory level of performance of the seed drill. An average size bullock can meet the draft.
2. By the use of a gravity flow orifice type metering mechanism no significant mechanical damage in metered seed was observed.
3. Eight to 10 % higher seed rate was observed in actual field condition as compared to laboratory test.
4. The seed drill had a field capacity of 0.8 to 1.0 ha/d.

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Tillage Effect on Yield, Quality, Management and Cost of Sugarbeet

by

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Abstract

The purpose or this research was to compare sugarbeet tillage methods in terms of yield, internal quality, operational parameters and cost and determine the most suitable methods in sugarbeet cultivation. The methods that were examined in this research were traditional soil tillage methods and five different methods that were considered to be feasible in Turkey. The methods were evaluated in terms of (1) sugarbeet yield and internal quality that include beet yield, sugar content, refined sugar content, refined sugar yield; (2) operational parameters that include fuel consumption, machinery time and labour requirements; and (3) effective area capacity and costs that include gross income, net income and total cost. In conclusion it was determined the best results were in S2 tilled by mouldboard plough and cultivator and S3 tilled by chisel between the soil tillage methods.

Introduction

Soil structure is one of the important factors that effect beet yield and quality, along with plant protection and pest control, seed structures and climate. For this reason, cultivation, which is the first step, has a special importance as with the other root crops. Seedbed preparation is the first step in obtaining high yield and quality. Incorrect preparation will cause negative results in next stage. Preparing the soil for sugarbeets often starts in the autumn of the preceding year. Most beet crops follow a straw crop. Shallow cultivation with disc-harrow can incorporate straw and stubble into the soil. This encourages germination of weeds including weed beet. After disc harrow preparation, ploughing is still the most popular primary cultivation. The soil must be moist enough to break-up as the furrow slice is inverted and no wetter. The furrow slices should be level, with tidy ends at the headlands. Freedom from holes and hollows is the key to a good sugarbeet seedbed (Jaggard, 1995).

The second step is being done in Turkey some time after the first ploughing (25-30 days according to climate) to maintain the effect of the plough. The field is also being left till to spring and cultivated by combi-crumler and then drilled by mechanical precision drilling

Table 1 Tillage methods carried out in this research

Treatment	Autumn application	Spring application
S1	Disc-harrow[1] + two times mouldboard plough[2]	Combi-crumbler[3] + drilling
S2	Disc-harrow + mouldboard plough + cultivator	Combi-crumbler + drilling
S3	Disc-harrow + Chisel	Combi-crumbler + drilling
S4	-	Inter row hoeing machine + drilling
S5	-	Rototiller
S6	-	Direct drilling

[1]X type with 24 discs, [2]Reversible with two semi digger body, [3]8 curved tines and 32 chisel tooth tines + 2 crumbling roller with large diameter + 2 crumbling roller with small diameter

machine. A maximum of 30 % crop residue on the surface is accepted in conventional tillage. For that reason, creating a defenceless surface against the water and wind erosion is unavoidable. Another disadvantage of conventional tillage is the moisture loss.

Conservation tillage is successfully applied in sugarbeet cultivation. Rydberg (1991) obtained 47.6 t/ha beet yield from the conventional tillage and 95-97 t/ha from direct drilling. Wing (1996) obtained 78.8 t/ha beet yield and 18.47 % sugar content from the direct drilling and 78.6 t/ha and 18.17 % sugar content from the conventional tillage respectively. Becker (1997) expressed that there wasn't any statistically difference between direct drilling and conventional tillage methods.

In this study the objective was to determine the effects of six different sugarbeet cultivation methods on yield, internal quality, operational characteristics and cost.

Material and Methods

Field experiments were conducted in Turkish Sugar Factories Corporation, Ilgin Experimental Station, which is near Konya in Turkey in 1999, 2000 and 2001. Ilgin has territorial climate. The soil contained 2.02 % sand/kg, 32.16 % silt/kg, 65.82 % clay/kg and has a specific gravity of 2.57 Mg/m^3.

The field experimental layout was randomised block with four replicates. Each plot was of 10 m length and 6.75 m width. Tillage methods carried out in this study are shown in **Table 1**. Fifteen rows (45 cm row distance and 8 cm seed distance in a row) were drilled at the beginning and 7 rows in the middle of the plots were harvested for yield estimation at the harvest time. Genetically monogerm sugarbeet varieties produced by KWS were drilled in this study. Average thousand seed mass of this seed is 11.5 g and the power of germination is 90 %.

Massey Ferguson (MF) 275 tractor (55 kW) was used in this study. The same mechanical precision drilling machine was used for all treatments in this research. Working width was 2250 mm, row distance 450 mm, working speed 4-5 km per hour and point of seed falling height 80 mm. A narrow cultivator share was adapted in front of each unit for drilling directly into stubble. Thus, the seed drill was prevented from being clogged with stubble and other residue and the seeds were placed at an exact depth in the furrow.

Beet, samples which were taken from the harvested plots, were analysed in the experimental laboratory in the Sugar Institute and sugar content and quality values were determined. Refined sugar content (RSC) and refined sugar yield (RSY) were calculated as follows (Reinefeld et al., 1974; Akoglu, 1978):

$RSC = SC - [0.343 \cdot (Na + K) + 0.094 \cdot \alpha - N + 0.29)]$

$RSY = RY \cdot RSC$,

where RSC is refined sugar content (%), SC is sugar content (%), Na is sodium content (meq Na/100 g), K is potassium content (meq K/100 g), α - N is harmful nitrogen content (meq N/100 g), S is dry matter (%), RSY is refined sugar yield (t/ha) and RY is root yield (t/ha).

Effective area capacity was calculated as follows:

$B = 0.1 \cdot b \cdot v \cdot k$,

Where B is effective area capacity of implements or machine (ha/h), b is working width (m), v is working speed (km/h), k is time coefficient.

In this research, the working speed of the tractor was determined by using chronometer with 10^{-1} second indicator. Fuel consumption was measured with scaled plastic cylinder mounted above the tank lid and expressed as litre per hour and litre per hectare by means of measured fuel consumption and working speed data.

$FC = 3.6 \cdot MFQ / t$

$FC2 = FC \cdot TR$,

Table 2 Sugarbeet yield (t/ha)

Treatments	Year			
	1999	2000	2001*	1999-2001*
S1	75.1	71.2	64.9 a	70.4 a
S2	75.8	72.4	64.3 ab	70.8 a
S3	72.2	71.2	61.4 ab	68.3 ab
S4	70.7	67.1	59.0 ab	65.6 b
S5	73.5	70.3	58.9 ab	67.6 ab
S6	71.3	70.5	55.0 b	65.6 b

* P < 0.01

Table 3 Sugar content, refined sugar content and refined sugar yield determined in each year

Treat.	Sugar content, %				Refined sugar content, %				Refined sugar yield, t/ha			
	1999	2000*	2001	1999-01	1999	2000*	2001	1999-01	1999	2000	2001	1999-01
S1	16.54	19.35b	18.41	18.10	13.36	17.22bc	15.48	15.35	10.00	12.3	10.00	10.8
S2	16.36	19.33b	18.73	18.14	13.27	16.92c	15.75	15.31	10.10	12.3	10.10	10.8
S3	16.51	20.14a	18.83	18.49	13.52	18.10ab	15.74	15.79	9.76	12.9	9.66	10.8
S4	16.18	20.35a	19.20	18.58	13.17	18.39a	16.09	15.88	9.34	12.3	9.46	10.4
S5	16.28	19.95ab	19.40	18.54	13.32	17.96ab	16.35	15.88	9.81	12.6	9.61	10.7
S6	16.82	20.21a	19.36	18.80	14.00	18.22ab	16.22	16.15	9.98	12.8	8.90	10.6

* P < 0.01

Where FC is fuel consumption per hour (l/h), FC2 is fuel consumption per area (l/ha), MFQ is measured fuel quantity (ml), t is time passing through the plot (s) and TR is time requirement per ha (h/ha).

Labour consumption was determined in order to calculate labour cost. Labour consumption consisted of working time of tractor operator and the other needed workers during the operation. The labour cost was calculated using daily fee (7.5 hour) of labourer working for Turkish Sugar Factories (22.73 $ for 2000 and 24.38 $ for 2001).

Machinery cost including fuel cost, labour cost, machinery hiring fee, herbicide cost and total cost and net income was determined. Labour and total machinery cost were calculated as follows:

LC = Lc • LCPH

TMC = MHF • TR,

Where LC is labour cost ($/ha), Lc is labour consumption (h/ha), LCPH is labour cost per hour ($/h), TMC is total machinery cost ($/ha) and MHF is machinery hiring fee ($/h).

Total cost and net income were calculated as follows:

TC = FC2 + LC + TMC

NI = GI - TC,

Where TC is total cost ($/ha), NI is net income ($/ha) and GI gross income ($/ha).

Results were evaluated according to F-test, variance analysis and Duncan methods. Also double and cumulative variance analysis were applied.

Results and Discussions

Sugarbeet Yield

Sugarbeet yield which was obtained in 1999, 2000 and 2001 and three years combined Duncan test results are given in **Table 2**. The highest yield was obtained in S2 with 75.8 t/ha, 72.4 t/ha, 70.8 t/ha in 1999, 2000 and three years combined results, respectively and in S1 with 64.9 t/ha in 2001. The lowest yield was determined in S4 with 70.7 t/ha, 67.1 t/ha in 1999 and 2000 respectively and in S6 with 55.0 t/ha, 65.6 t/ha in 2001 and three years combined results respectively.

There was no significant difference between the methods in 1999 and 2000 as shown in **Table 2**. However the difference between the methods was significant in 2001 and three years combined results ($p < 0.01$).

Sugarbeet Internal Quality

Sugar content, refined sugar content and refined sugar yield results are given in **Table 3**.

The highest sugar content was obtained in S6 with 16.82 % in 1999, 20.35 % in S4 in 2000, 19.40 % in S5 in 2001 and 18.80 % in S6 in three years combined results. The lowest sugar content was determined in S4 with 16.18 % in 1999, 19.33 % in S2 in 2000, 18.41 % in S1 in 2001 and 18.10 % in S1 in three years combined results, respectively.

The difference between the methods was significant in 2000 ($p < 0.01$), however the difference between the methods was not significant in the other years and combined results. The highest refined sugar content was obtained in S6 with 14.00 % in 1999, 18.39 % in S4 in 2000, 16.35 % in S5 in 2001 and 16.15 % in S6 in three years combined results. The lowest sugar content was determined in S4 with 13.17 % in S4 in 1999, 16.92 % in S2 in 2000, 15.48 % in S1 in 2001 and 15.31 % in S2 three years combined results, respectively. The difference between the methods was significant in 2000 ($p < 0.01$), however the difference between the methods was

Table 4 Some measured parameters in each year

Year	Treatments	Fuel consumption		Labor consumption, h/ha
		l/h	l/ha	
2000	S1	31.04	51.50	7.80
	S2	29.08	55.80	8.60
	S3	23.16	30.10	5.00
	S4	18.93	18.10	2.50
	S5	24.33	34.20	4.60
	S6	10.53	7.70	1.30
2001	S1	31.43	40.10	6.10
	S2	30.43	44.70	6.90
	S3	26.21	31.10	4.30
	S4	20.16	19.60	2.50
	S5	25.81	24.80	4.30
	S6	11.23	8.00	1.20

Table 5 Cost, Gross margin and net income of the methods for 2000-01, $/ha

Treat.	Fuel cost		Labour cost		Machine cost		Total cost		Gross margin		Net income	
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
S1	60.20	38.00	37.80	31.20	63.40	37.60	161.40	106.80	3,750	2,192	3,589	2,085
S2	38.80	26.30	25.80	22.40	38.20	23.30	102.80	72.00	3,810	2,208	3,707	2,136
S3	20.90	18.30	19.00	14.40	35.00	18.10	74.90	50.80	3,904	2,119	3,829	2,068
S4	12.60	11.50	7.80	8.20	14.60	11.40	80.10	76.20	3,715	2,078	3,635	2,002
S5	23.90	19.90	14.10	14.10	23.60	17.30	106.70	96.40	3,815	2,096	3,708	2,000
S6	5.40	4.70	4.10	4.00	7.90	5.90	62.50	59.70	3,876	1,952	3,814	1,892

not significant in the other years and combined results.

The highest refined sugar yield was obtained in S2 with 10.1 t/ha in 1999, 12.9 t/ha in S3 in 2000, 10.1 t/ha in S2 in 2001 and 10.8 t/ha in S1, S2 and S3 in three years combined results. The lowest sugar content was determined in S4 with 9.34 t/ha in 1999, 12.3 t/ha in S1 and S2 in 2000, 8.90 t/ha in S6 in 2001 and 10.4 t/ha in S1 in three years combined results, respectively. The difference between the methods was not significant in terms of refined sugar yield in each year.

Operational Parameters

Some measured parameters are given in **Table 4**. The lowest fuel consumption was measured in S6 with 7.7 and 8.0 l/ha in 2000 and 2001 respectively. The highest fuel consumption was measured in S2 in each year.

Cost Analysis

The calculated cost data for 2000 and 2001 are given in **Table 5**. The highest total cost was observed in S1 in each year. The lowest total cost was observed in S6 in 2000 and in S3 in 2001 respectively.

The highest net return was obtained in S3 with 3,829 $/ha in 2000, S2 with 2,136 $/ha in 2001 and S3 with 2,949 $/ha in two years combined results (**Table 5**). The lowest net return was obtained in S1 with 3,589 $/ha in 2000, S6 with 1,892 $/ha in 2001 and S4 with 2,819 $/ha in two years combined results.

Conclusions

The results of this study were summarised as follows:

1. The highest sugarbeet yield according to three years combined results was obtained in S2 with 70.8 t/ha. The yield was 70.4 in S1 and 68.3 in S3. The lowest yield was determined in S6 with 65.6 t/ha. The highest refined sugar yield and the lowest refined sugar content were also measured and calculated in S1 and S2. S6 gave the highest sugar content and refined sugar content. On the other hand, the lowest refined sugar yield was observed in S4 and S6.
2. The highest values in terms of operational parameters such as machinery time requirements, fuel and labour consumption were obtained in S1 and S2 and the lowest were S6.
3. When the methods were compared in terms of cost, S1 was determined to have the highest cost according to two years average results. The lowest cost was obtained in S6 and S3. Because the highest net income was determined in S3, chiselling may be a good alternative to the mouldboard plough. The close values were obtained between S2 and S3 in terms of net income. The lowest net income was determined in S4 and it was observed that the S6 had the lowest gross margin. In addition S6 gave better results than S1 in terms of net income.

In conclusion, S2 and S3 are regarded as the most suitable tillage methods in Middle Anatolia conditions in Turkey. In addition it was determined that S6 is successfully applicable in sugarbeet cultivation in the same area.

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Potential for No-Tillage Agriculture in the Pandamatenga Vertisols of Botswana

by

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Abstract

The objective of this paper was to conduct an extensive literature review to assess the status and potential of no-tillage as an alternative tillage system on vertisols in the Pandamatenga farms, Botswana. Farmers in the area have failed to produce satisfactory crop yield levels because of problems associated with management of the soils using conventional tillage systems.

Information from literature showed that no-tillage system was effective in improving soil quality, water management, and crop yield in the area. However, there is a need to carryout in-field trials to monitor changes in the soil quality and the environment under no-tillage and conventional tillage systems.

Introduction

Pandamatenga region lies in the north-east fringe of Botswana between latitude 18º 26' to 18º 43' South, and longitude 25º 27' to 25º 37' East (**Fig. 1**). The Pandamatenga region covers a land area of 280,380 ha. The Pandamatenga farms covers only 25,074 ha of this total land area.

The area is generally flat, with a gentle slope, and rain water flows following natural drainage routes. The vegetation is extensive grassland savanna in association with mophane (Colophospermum mophane) and Acacia species.

The climate is subtropical with hot, rainy summers and cold, dry winters. The mean annual rainfall is 626 mm with annual totals varying between 394 and 1,050 mm. A substantial proportion of rain falls between October and April in short duration high intensity storms.

Vertisols such as the ones found in the Pandamatenga region are considered good farming soils, but they have unique properties that require special management if full yield potential is to be realized. Most commercial and small-holder farmers in the Pandamatenga region practice conventional tillage to grow sorghum (Sorghum bicolor L.), sunflower (Heliantus annuus L.), and occasionally cotton (Gossypium sp.). Under conventional tillage system, the whole field is ploughed using either a moldboard or disc ploughs followed by 1 to 2 harrowings before seeding. This system destroys soil structure leading to problems related to soil degradation (Gupta et al., 1989) and compaction. Soil compaction is caused by high field machinery traffic as well as continuous cropping that result in an increased exposure of soils to high intensity storms (Kayombo and Lal, 1993). The long-term effect is the decline in crop yields (Yao-Kouame and Yoro, 1991).

Problems of accelerated soil erosion, high costs of energy inputs, and low yield returns associated with conventional tillage methods of seedbed preparation have led to increasing adoption of no-tillage systems for production of row crops (Landers, 2001). No-tillage system involves minimization of mechanical seedbed preparation and promotes reliance on herbicides and cover crops to kill or suppress weed growth. Seeding is done on an undisturbed or minimally disturbed soil allowing residue mulch to accumulate on the ground.

Applicability of no-tillage system however, is limited to certain soil types, crops, and ecological regions. The general criteria requires that (1) regions be characterised by high intensity rainfall at the beginning of the rainy season following a dry period, (2) regions should have two or three periods of seven to ten rainless days during the rainy season, and (3) total rainfall should exceed 500 mm (Thomas et al., 1984). **Table 1** shows that the Pandamatenga region satisfies these criteria, and thus no-tillage system could appropriately be practiced in the area. In addition to the above criteria, successful crop establishment with a no-tillage system also depends on the antecedent soil conditions and the land use history.

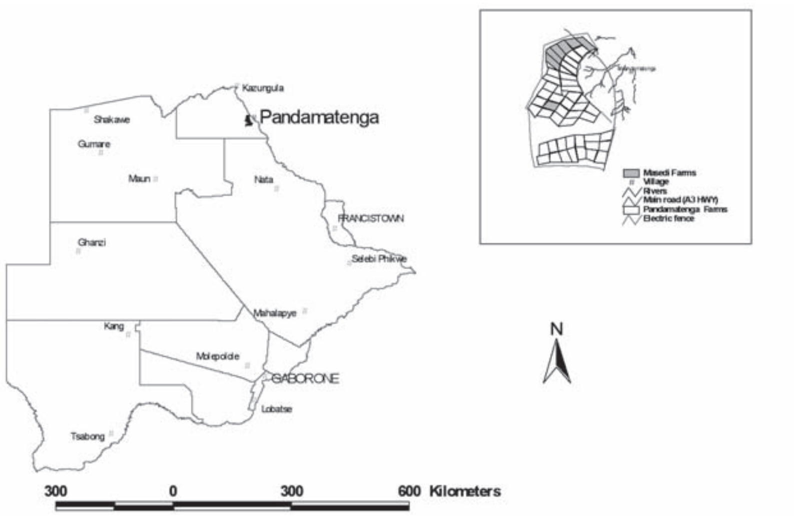
Although Pandamatenga vertisols have a high crop production potential, their development is constrained by the requirement for special management practices. Furthermore, the scantly available information in Botswana on vertisol management limits the successful application of no-tillage for agricultural production. The Debswana Mining Company's farming project, namely, Masedi Farms (Pty.) Ltd was started in 1998 to demonstrate the viability of no-tillage for the production of sorghum and cotton under rain-fed farming conditions in the Pandamatenga region (Botswana Gazette, 2002a). Masedi Farms Ltd operates on seven farms with a total area of 3,500 ha (**Fig. 1**).

Masedi Farms Ltd have for two successive years (2000-2001) produced 5 t/ha of sorghum from its farms (BOPA, 2002). Previously, farmers practising conventional tillage in the area had managed only about 0.3 t/ha of sorghum. As a result, some farmers/outgrowers in Pandamatenga have joined Masedi Farms Ltd in practising the no-tillage technology (Botswana Gazette, 2002b) and are also getting increased yield.

With these recent developments in Pandamatenga, the need for no-tillage research cannot be over-emphasized. Long-term and large-scale studies are necessary to generate data on yield levels, nutrient requirements, use of agrochemicals and equipment. The environmental effects of long-term use of herbicides under no-tillage system need to be investigated in order to understand the fate of agrochemicals and minimize the dependence on herbicides as the preferred mode of weed control. Minimizing energy-related inputs of tillage, fertilizers, and monitoring changes in the physical, chemical and biological status of the soil are other major areas that deserve a high attention.

The objective of this paper is to assess the status and potential of no-tillage agriculture in the Pandamatenga area using farmer experiences and available literature.

Fig. 1 Map of Botsuwana showing the location of Pandamatenga farms. Map on the insert is the expanded view of the farms



Methodology

The researchers visited the Pandamatenga area to familiarize themselves with the farming activities. During the visit, meetings were held with the head of agricultural research station and the farm manager at Masedi Farms Ltd. Field tours were made to verify the soil characteristics described in the literature as well as by the farmers. Literature was also reviewed regarding management and crop performance under no-tillage in areas with conditions similar to those in Pandamatenga. Assessment for the potential of no-tillage was based on apparent improvement in soil conditions achieved to date, and as described in the literature.

Soil Quality Status

Soil quality is defined as the capacity of a soil to function within a natural or managed ecosystem boundaries, to sustain plant and animal productivity, to maintain or enhance water and air quality, and to support human health and habitation (Soil Science Society of America, 1995; Doran and Parkin, 1994). Soil quality can be determined by evaluating soil properties that are subject to change as a result of the tillage practice imposed on them. These include the physical, chemical and biological characteristics of the soil.

Physical Properties

Pandamatenga vertisols exhibit characteristics that are typical to similar soils found in other parts of the world. These include formation of cracks down to 50 cm level and that are at least 5 cm wide. The soils occur on a lacusterine plain and are mostly imperfectly drained. When dry, they have a very hard consistence, but are plastic and sticky when wet. Hence, they are friable only over a narrow moisture range. Bulk density for Pandamatenga vertisols ranges from 1,300 kg/m^3 in the untilled topsoil to 1,370 kg/m^3 in the subsoil (Moganane et al., 1990).

Studies that demonstrate the effects of the no-tillage system on soil physical properties appear to be nonexistent in Botswana. However, most studies from other parts of the world show general improvement of the soil quality under no-tillage, while a few others (Kersten and Hack, 1991) have shown contradictory results. Gill and Aulakh (1990) reported that the no-tillage treatment gave the highest wheat yield and lowest bulk density on Zambian oxisols under rain-fed conditions when compared to conventional tillage. Other findings that contradict this result indicate that suitability of no-tillage is dependent on both the soil type and the crop being planted.

Dalal (1989) compared the effects of long-term conventional tillage with no-tillage on vertisols. He found that the aggregation index of the surface soil (0-10 cm) was higher under no-tillage. This is indicative of improvement in soil quality because of no-tillage practice. Aggregation is caused by the presence of organic matter in no-tillage system. The decomposing plant material releases organic colloids that act as bonding agents of the soil particles (Brady, 1984). A well-aggregated soil has a better pore system, making it easy for air, water, and nutrients to flow through the soil matrix.

In Australia, Marley and Littler (1990) compared several reduced tillage practices, including no-tillage, on the production of wheat grown on cracking clays. They found that the no-tillage, which retained stubble, gave the highest water storage efficiency. Holland and Felton (1989) reported similar results in a study investigating the response of grain sorghum to no-tillage. Water storage under no-tillage is aided by the increased retention of crop residue and organic matter. Crop residue acts as a mulch that reduces soil temperature and hence evaporation. Water also infiltrates better through the crop residue than on bare ground (Chan and Heenan, 1996). Organic matter stabilises the soil structure leading to high soil porosity and increased water infiltration.

The Pandamatenga soils have a poor structure that is not well drained. Initial infiltration rates on naturally occurring soils average 22.7 cm/hr while the final infiltration rates average 0.3 cm/hr. An increase in organic matter content will aid in retaining soil moisture, improve soil porosity and support aggregation of the soil particles.

Chemical Properties

Soil chemical properties include the cation exchange capacity (CEC), soil reaction (pH), exchangeable cations, organic matter, and macro and micro-nutrients. Organic carbon, which is used for estimating organic matter, is relatively low in most soils of Botswana due to high soil temperatures that promote organic matter decomposition. Further, there is also little accumulation of plant residue because of low rainfall and frequent drought. By comparison, Pandamatenga vertisols have better chemical properties for crop production than other soils in Botswana. Consequently, the use of fertilizers by the farmers is still low. However, available phosphorous and nitrogen are low in Pandamatenga vertisols, and as such the soils will respond to addition of nitrogen and phosphorus fertilisers by producing more yield.

No-tillage influences chemical properties of soils positively. Dalal et al. (1991) measured organic carbon, total nitrogen, pH and microbial biomass in a vertisol in Australia after twenty years of no-tillage. The organic carbon, total nitrogen and microbial biomass levels were found to have increased significantly in the top 25 cm of the soil. A strong stratification with depth was also found with all the soil properties, suggesting that no-tillage and residue retention promoted stratification of the chemicals.

The fibre content of the soil is reported to have increased on the Masedi Farms Ltd since the commencement of no-tillage farming in 1998. This is in agreement with findings of Zibilske et al. (2002) and Saffigna et al. (1991) who found that organic matter of the surface soil increased under no-tillage. Other nutrients, specifically zinc and manganese, are also reported to have reached optimum levels at Masedi Farms Ltd, such that they do not need to be added.

Soil Life

Living organisms in the soil consist of micro-organisms such as bacteria, fungi, algae, protozoa, nematodes, insects, and earthworms. The breakdown of organic matter to release nutrients to plants largely depends on these organisms. Where there is no addition of fertilizer, plants rely on organic matter as their source of nutrients. In undisturbed soils, most of

Table 1 Five-years (1997-2002) rainfall amounts (mm) for the Pandamatenga farms

Year	Month									
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total
1997 /98	17.8 (2)	25.8 (6)	60.4 (5)	68.9 (6)	143.5 (12)	68.1 (6)	82.5 (2)	6.5 (1)	-	473.5 (42)
1998 /99	-	7.6 (1)	152.9 (6)	96.7 (8)	72.2 (8)	54.2 (3)	-	-	-	429.8 (26)
1999 /00	-	5.2 (1)	45.8 (5)	119.1 (10)	181.1 (12)	287.8 (8)	64.2 (5)	-	-	703.2 (42)
2000 /01	3.5 (1)	23.0 (1)	89.4 (8)	102.9 (13)	25.5 (2)	192.6 (11)	185.7 (6)	21.7 (2)	-	644.3 (44)
2001 /02	-	37.7 (4)	87.2 (8)	101.9 (10)	151.0 (8)	44.7 (5)	29.2 (2)	46.2 (2)	-	497.9 (39)

Note: Figures in brackets indicated total number of rainy days
Source: Padamatenga Agriculture Research Station

the nutrient cycling, roots, and most biological activities are found in the top 20 to 30 cm, known as the rhizosphere. In the rhizosphere, the plant, soil and soil micro-organisms are symbiotic. Plants provide the carbon and food source for soil organisms that bind the soil particles into aggregates and recycle soil nutrients. Soil provides the habitat, water and mineral nutrients for both soil organisms and plants. Management techniques that change the amount and quality of carbon going into the soil as either residue or root exudates will effect change in the soil biology.

Brady (1984) defined soil management as the sum of all tillage operations, cropping practices, fertilizer, soil amendments, and other treatments applied to the soil for the production of plants. This definition puts emphasis on the link between all farming practices and the soil. Tillage directly affects soil porosity and the placement of residues. Porosity determines the amount of air and water the soil can hold. Residues affect the soil surface temperature, rate of evaporation and water content as well as nutrient loading and their rate of decay. This leads to more soil life and hence higher nutrient loading capacities and a more continuous release of nutrients.

Hughes and Herridge (1989) found that plant growth, seed yield, and nodulation index of soybean increased under no-tillage. Nitrogen fixation was also found to be higher in the no-tillage plots. Under no-tillage system, the organic matter decomposes more slowly. This occurs because the low nitrogen content of crop residues, especially cereal crops slows the feeding of micro-organisms (Grant and Bailey, 1994).

Earthworm numbers increase dramatically under no-tillage system. In a long-term dryland tillage experiment, Clapperton et al. (1997) found as many as 300 earthworms per square metre under no-tillage system compared with none under conventional tillage. In the same experiment, there was significantly lower incidence of common root rot under no-tillage compared with conventional tillage, demonstrating the long-term benefit of maintaining the soil habitat. Masedi Farms Ltd observed an increase in earthworm population over a period of 4 years. Earthworms are usually a sign of good soil quality since they improve the physical properties of soils.

Managerial Aspects of No-Tillage

The Pandamatenga vertisols exhibit two important characteristics that dictate the management system that can be successfully used to produce crops. The soils are soft and plastic when wet, and very hard and with deep cracks when dry (Arup-Atkins, 1990a). In addition, the area receives relatively high rainfall averaging 600 mm and making it difficult to access the fields immediately following rainfall. These two factors result in high draught requirement, high erodibility of the soil, large strong clods in the dry seedbed, and a narrow range of optimum water content for tillage (Arup-Atkins, 1990b).

Crop Production

Management of vertisols for crop production varies regionally depending on whether they occur in the humid tropics, or in temperate areas. Problems that are generally experienced in one area may be of little consequence in the other. For example, the large clods formed by tillage in the tropics are usually disintegrated by the freezing and thawing phenomenon in the temperate region and so there is little need for follow-up tillage unless it is done for weed control. On the other hand, in the tropics, secondary tillage is required to break down the clods since there is no freeze-thaw effect. In addition, vertisols in the sub-humid tropics as in the Pandamatenga, tend to have specific requirements for water management (Ahmad and Mermut, 1988) to remove excess water following rainfall.

Sorghum was tried under commercial production in the Pandamatenga region in the early 1950s. Since then, the yields have been as low as 0.3 t/ha. Arup-Atkins, (1990c) reported a low sorghum suitability rating for the area while the suitability for maize was very marginal. The main constraint to improved yields was identified as slow soil drainage and poor workability of the soil. Some farmers employed tillage methods similar to the ones they previously used in arenosols that are common in most of the country where arable production is practiced. However, more recently, Masedi Farms Ltd was able to obtain yield levels of up to 5 t/ha and 2.8 t/ha for sorghum and cotton respectively (BOPA, 2002). The high yield is also evident in other crops such as sunflower and cotton grown by Masedi Farms Ltd. The success of Masedi Farms Ltd is attributed to the use of fertilizers and adoption of no-tillage system as opposed to conventional tillage system that was used by previous farmers, who also applied less fertilizer.

Mechanization

Under conventional tillage system, tillage equipment is used primarily to prepare the seedbed, control weeds, and incorporate fertilizer and manure (Tapela and Colvin, 2002). The narrow range of optimum water content for tillage and the clotting nature of vertisols present difficulties in adopting conventional tillage practices. Clods make it necessary to follow primary tillage operations with a cultivator to level the seedbed. As a result, more field operations are required and there is increased energy requirement. However, under no-tillage, the seedbed is maintained rather than being rebuilt every year. It is therefore not necessary to plough the soil every year. Specialized equipment such as air seeders are used to plant the crops with minimal disturbance of the soil. Only a narrow strip of about 5 cm along the planting area is disturbed. Practising controlled traffic, where the same travel paths are maintained for all field machinery in all years, also minimizes compaction. The reduced need for tillage operations saves on fuel and labour requirements. During the wet season (October to April) in Pandamatenga, some months may have only 8 days when fieldwork may be done effectively as the fields become inaccessible due to water logged soils. There is thus a narrow window (November 15 to December 15) when grain crops may be planted. Therefore, no-tillage provides an alternative that can be used to ensure timely execution of field operations. Additional equipment required under no-tillage system include various chemical application equipment for spraying herbicides, pesticides, and fertilizers.

Chemical Use

The use of herbicides and pesticides by the Pandamatenga farmers is on the increase. The types of chemicals used also vary as shown in **Table 2**. However, the use of herbicides (Atrazine, Glyphosate and 2,4-D-Amine) to control weeds on vertisols can be hazardous because of the high initial infiltration rate through the cracks resulting in contamination of underground water.

The almost zero infiltration when the soil is wet can also contaminate ground surface water bodies. This is especially true if the farmer is not experienced such as those in the Pandamatenga Outgrowers Association (Botswana Gazette, 2002b). These are small farmers who emulate methods used by Masedi Farms Ltd, and most are without the necessary training to manage herbicides. It is difficult to manage modern farming without the assistance of consultants, especially with regard to soil management. In that regard Masedi Farms Ltd conducts soil tests every season to determine the level of soil nutrients and make management decisions concerning fertilizer requirement.

Conclusions

No-tillage system has only been practised in Botswana on a large scale since 1998 by Masedi Farms Ltd. Therefore, research literature on the subject is scanty. Available literature on the performance of no-tillage is from other countries that have similar soils and climatic conditions. Based on this literature and farmer experience in the Pandamatenga area, it is evident that no-tillage system has a potential to replace conventional tillage system. The increased yield returns obtained by Masedi Farms Ltd is attributable to a combination of no-tillage system and increased use of fertilizer. However, the effect of each factor needs to be isolated so that no-tillage can be assessed adequately. In spite of that, the success of Masedi Farms Ltd has led to the adoption of no-tillage by the Pandamatenga Outgrowers Association. Positive results associated with no-tillage system include, improved soil organic matter content, increased soil biological activity, higher nutrient level, lower bulk density, and increased water infiltration rates. The positive change is noticeable only after four years of practicing no-tillage. The long-term implications of adopting no-tillage are unknown at the present moment.

No-tillage system relies on heavy use of agricultural chemicals, which may impact negatively on the environment if not well managed. The economic benefits also take time to be achieved as the high cost of specialized machinery take a long time to be offset. As a result, only long-term research that can monitor no-tillage farming will answer concerns about the long-term implications of no-tillage in the Pandamatenga area. It is therefore recommended that further and more intense studies be carried out to evaluate the environmental and economic implications of adopting no-tillage system.

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Table 2 Types of pestcides and herbicides used by Pandamatenga farmers

Crop	Pestcide	Herbicide
Sorghum	Endoflo	Lasso (alachlor)
	Supermatrine	Roundup (glyphosate)
	Mospilan	2,4-D Amine
	Cypermethrin	MCPA
	Thionex	Atrazine
	Metasistox	
	Demeton	
	Sulmethine	
	Phonex	
Sunflower	Parathion	

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Development and Performance Test of a Laser Controlled Land Leveling Machine

by

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Abstract

This study developed a new lower-cost laser controlled leveling system, integrated with medium-sized and small-sized tractors, for farmland leveling. The system consisted of a laser transmitter for creating a laser beam scanned altitude level reference, a laser signal receiver, an intelligent hydraulic controller, a hydraulic control unit and a leveling bucket. A commercially available 644 nm laser transmitter was used and the main effort was in the development of the other four components and integration. Experiments were conducted for the performance test. The results showed that the system worked properly with an accuracy of ~ 3 cm.

Introduction

The even level surface of a field is one of the key factors influencing the efficiency and effect of surface irrigation. More than 20 % irrigation water is wasted due to poor farm design and uneven surface of the fields (Muhammad Asif et al., 2003). Unevenness of the fields leads to the delay of tillage and crop establishment options. Uneven fields also contribute to poor crop stands, increased weed burdens and inconsistent maturity of crops (Rickman, J. F.; 2002). It is of significance to optimize water-use efficiency, improve crop establishment and reduce the irrigation time and effort required for crop management. Since the 1980's, laser leveling technology has been employed for land leveling and other applications in the developed countries. Compared with the conventional land leveling methodologies that use an animal leveling board or tractor blade, the laser controlled land leveling method has high efficiency and high accuracy (Li et al., 1999).

There are several available commercial laser controlled systems for land leveling applications that include a LL600 laser transmitter integrated with a R2S-S laser signal receiver and a control box (Trimble, 2002), a RL-type laser transmit-

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ter integrated with a LS type laser signal receiver and a controller (Topcon, 2002), and an EAGL type laser transmitter integrated with an OMNI type laser signal receiver and a MODEL 304 controller (AGL, 2005). In order to obtain the full potential of these laser controlled systems, they are integrated with large-sized tractor to draft a large leveling bucket to achieve high efficiency of land leveling. However, their high cost and hydraulic support of the large-sized tractor limits their extension in China. Therefore, there are several studies on the development of laser controlled leveling systems or their components in China. Jia et al. (1995) and Zhu et al. (1996) developed a laser controlled systems, including a laser transmitter using a He-Ne laser, a laser receiver using photoelectrical sensors and a hydraulic controller. Both systems were not put into practice due to their small working ranges (< 100 meters), lower accuracies (> 10 centimeters), and instability. There are two reports on laser transmitter development by Ma (1997) and Ji (1999) using a gas laser, but they did not attempt to develop the other two components for the laser controlled system: laser signal receiver and hydraulic controller. Meanwhile, several investigations on the leveling bucket and the hydraulic control unit were made (Yang et al., 2002; Han, 2003; Luo et al., 2004; Hou et al., 2005). The former two studies were integrated with the Trimble laser controlled system, while the latter two ones were tested using the laser controlled system developed in this study.

While laser controlled systems for land leveling are commercially available, their trend to integrate with large-sized tractor systems and their high cost become major obstacles in their dissemination in agriculture, especially in less developed countries. This study developed a new lower-cost laser controlled land leveling system for a possible adoption in precision farmland management and water saving irrigation with three objectives:

1. To develop a laser controlled system for land leveling machine, involving the integration of a laser transmitter and the development of a laser signal receiver and a hydraulic controller.
2. To develop a hydraulic control unit and a leveling bucket.
3. To integrate the laser controlled system with the hydraulic control unit and the leveling bucket to conduct performance tests in the fields.

Design of Laser Controlled Leveling System

The laser controlled system consisted of a laser transmitter, a laser signal receiver, and a hydraulic controller. The principle of laser controlled leveling system is shown in **Fig. 1**. The laser transmitter emitted a rapidly rotating laser beam to create a geographical parallel altitude reference plane over the field, which was picked up by the laser signal receiver mounted on the mast of the leveling bucket. According to the response from the laser signal receiver, the hydraulic controller mounted on the cab of tractor carried out corresponding operations to raise or lower the leveling bucket by the hydraulic control unit using a hydraulic valve and a cylinder.

In this study, a new laser controlled system was developed. A commercially available laser transmitter was used to provide a laser reference plane in this system. The main effort was in the development of a laser signal receiver, a hydraulic controller, a hydraulic valve and a leveling bucket and their integration.

The Laser Transmitter

A laser transmitter (JP3, Suzhou FOIF Co., Suzhou, China) using a 644 nm semiconductor laser diode was employed as the laser signal generator. The horizontal accuracy of JP3 was ± 20 seconds and the operating diameter was 300 meters. The rotating rate was set at 600 rpm.

The Laser Signal Receiver

Acting as a bridge to connect the laser transmitter with the hydraulic controller in the laser controlled leveling system, the laser signal receiver real-time detected laser signals from the laser transmitter and processed the signals before being sent to the hydraulic controller. In the development of the laser receiver, major problems were faced

Fig. 1 Principle of laser controlled land leveling system

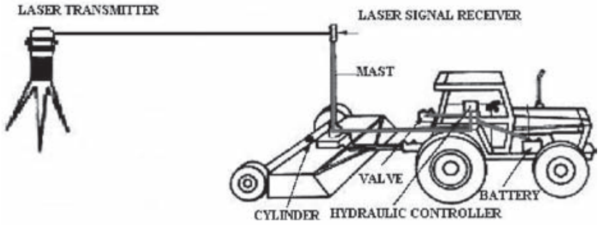
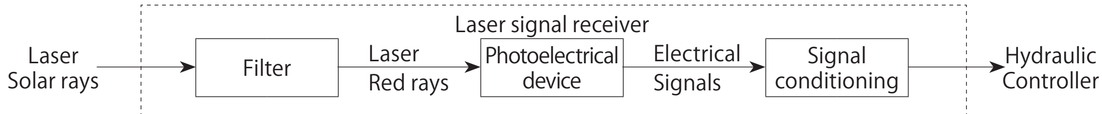


Fig. 2 Structure of the laser signal receiver



with the intensive disturbance of solar rays and the processing of low-power electrical signals transduced by photoelectrical device. The structure of the laser signal receiver is shown in **Fig. 2**.

Optical filtering technology, using optical absorptive filter integrated with red optical glass, was employed to attenuate the noise influence of the solar rays. A total of thirty-two silicon photoelectrical devices (2CR93, Beijing Photoelectronic Devices Factory, Beijing, China) with a size of 20 x 5 mm and an incident angle of over 120° were used to transduce the laser signal into electrical signal. These photoelectrical devices were laid out in eight rows and four columns. A laser signal sensing column with a height of ~ 18 cm was built. A signal conditioning unit was developed for laser-transduced electrical signal processing. The engineering development of the laser signal receiver was described in detail by Lin et al. (2005).

The Hydraulic Controller

The hydraulic controller was an implementer for the response from the laser signal receiver. The block diagram of the hydraulic controller is shown in **Fig. 3**. A single-chip microprocessor (AT89S51, ATMEL, San Jose, CA, USA) was integrated with an embedded chip Max813 (Maxim, Sunnyvale, Ca, USA) and two Solid State Relays (JGT 3FA, Beijing ZhengFangYongHeng Ltd., Beijing, China). The four altitude levels, labeled with "Higher", "High", "Low" and "Lower", were related with each two rows of photoelectrical devices in the layout of the laser signal receiver. The hydraulic controller was designed with two operation modes: Auto and Manual. In the Auto mode, the laser controlled system could automatically adjust the leveling bucket only according to the response of the laser signal receiver, while the Manual mode was often used to raise the leveling bucket with over load. In the development of embedded software for the hydraulic controller, the combination of the input altitude signals was required to check whether or not it was valid. The altitude level was extended from original four levels to six ones, using fuzzy control rules, to understand the exact relative altitude related the laser signal with the laser signal receiver. The output responses of the hydraulic controller were 12 volt rectangle waves with different pulse duration ratios (40 %, 60 % and 80 %) related to the relative position. The engineering development of the hydraulic controller was described in detail by Si et al. (2004) and Lin et al. (2005).

The Hydraulic Control Unit

The hydraulic control unit was developed to implement the corresponding operation according to the output of the hydraulic controller. The principle of the hydraulic control unit is shown in **Fig. 4**. The hydraulic system of the tractor was used to supply oil to raise and lower the leveling bucket. The main effort was concentrated on the hydraulic valve. The engineering development of the hydraulic valve was described in detail by Hou et al. (2005).

The Leveling Bucket

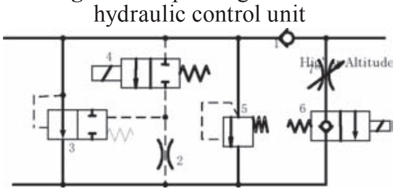
Based on the original bucket design by Rickman, the leveling bucket was modified with a size of 2.2 m x 1 m x 1 m for a medium-sized tractor, including pneumatic tire assembly, bucket type leveler assembly and hitch frame assembly (**Fig. 5**). It could be produced by local industries. The specifications for the leveling bucket design were described in detail by Rickman (2002).

Performance Test

System Tests

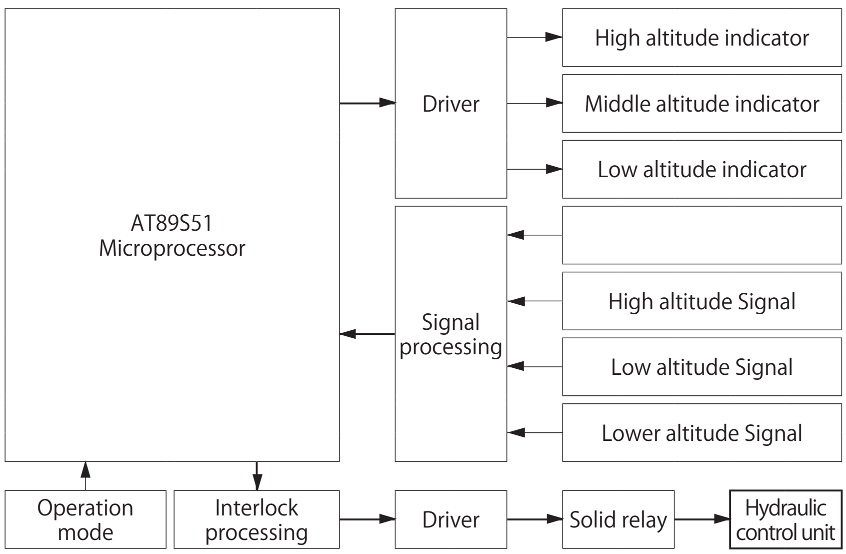
Experiments for measuring the effective receiving height of the laser signal receiver were conducted by using the JP3 laser transmitter (**Fig. 6**). The effective receiving height was ~ 18 cm and had a slight fluctu-

Fig. 4 Principle diagram of the hydraulic control unit



1: Single check value, 2: Throttle, 3: Hydraulic control directional control valve, 4: Two position three-way solenoid directional control valve, 5: Relief valve, 6: Solenoid control valve, 7: Speed regulating valve

Fig. 3 Block diagram of the hydraulic controller



ation due to the decrease of the laser power and the diffusion of the laser.

The laser controlled system, including the JP3 laser transmitter, the laser signal receiver and the hydraulic controller was tested in the laboratories and it did work properly.

Field Tests

Since 2002, laser land leveling experiments have been conducted at Beijing, Handan, Guangzhou and Sichuan using the laser controlled system. The leveling bucket was drafted by a moderate-power tractor at a speed of ~ 5 km/hr. The JP3 laser transmitter, set at the rotating rate of 600 rpm, was mounted on a tripod in the field. The laser signal receiver was mounted on a mast of the leveling bucket. The hydraulic controller was mounted closely to tractor operator. The 3-way 12 VDC hydraulic valve was integrated with the hydraulic system of the tractor for the leveling bucket.

The effect of land leveling using the laser controlled system was evaluated by comparison of the even level of the original and leveled fields, described by standard deviation. Grid sampling method was employed to measure the relative altitude of the fields. The relative altitude was determined using the laser surveying system, including a JP3 laser transmitter, a scaled rod and a portable laser signal detector. The terrain maps of an original and leveled field in a recent leveling experiment, conducted on April, 2006 at Beijing using the laser controlled leveling system, are shown in **Fig. 7**.

The standard deviation was calculated to evaluate the even level of field by the expression:

$$S_d = \sqrt{\sum_{i=1}^{n}(h_i - h)^2/(n-1)} \quad \text{.................(1)}$$

where, S_d was the standard deviation, n was the total number of sampling readings, hi and h represented the sampling reading at the ith spot and the mean one, respectively. Several laser land leveling experiments in 2004-2006 were focused on performance test of the laser controlled system (**Table 1**). The former two year (2004-2005) experiments were conducted mainly for the accuracy of the laser controlled system integrated with hydraulic control unit, while the latter year (2006) tests aimed at the stability of the whole laser controlled land leveling system in three fields, totally ~ 20 hectares. The accuracy of the laser controlled leveling system was ~ 3cm. However, the efficiency of land leveling was less and was estimated with ~ 0.20 hectare per hour. Studies on land leveling programming in route for tractor and division into subfields based on three-dimensional topography would be attempted to promote the efficiency of leveling.

The size of the leveling bucket, the power of tractor and the proficiency of the driver also influenced the leveling efficiency. A 300-horsepower tractor was capable of drafting a leveling bucket with a width of 7-8 m, while a 50-60 horsepower tractor dragged a bucket with a width of ~ 2 m.

Table 1 Evaluation of land leveling experiments using the laser controlled system

Year	Area, hectare	Standard deviation before leveling, cm	Standard deviation after leveling, cm	Leveling efficiency, ha/hr
2004	1.7	7.8	3.1	0.20
2005	0.6	5.0	2.2	0.19
2006	20	8.2	3.0	0.24

Conclusions

A new lower-cost laser controlled land leveling system, an integration of the JP3 laser transmitter, the laser signal receiver, the hydraulic controller, the hydraulic control

Fig. 5 The leveling bucket for land leveling machinery modified based on the original leveling bucket designed by Dr. Joe Richman

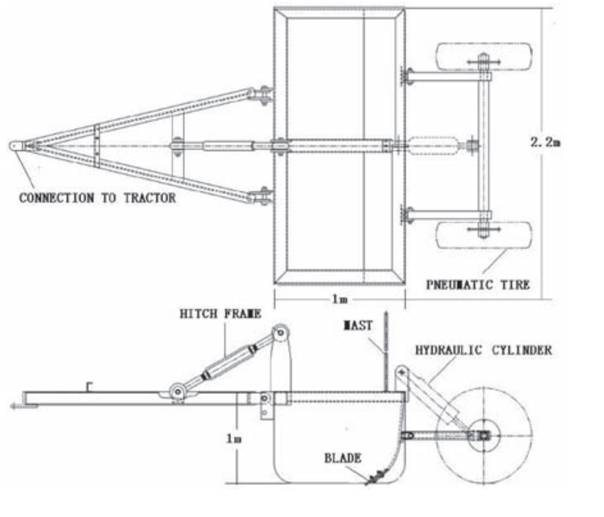
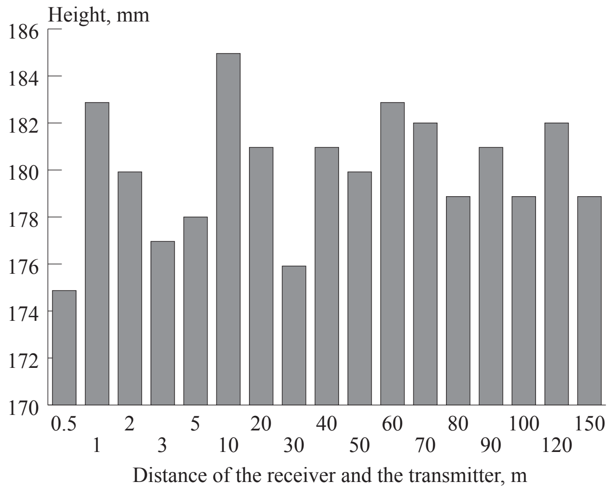


Fig. 6 Effective receiving height of the laser signal receiver related with the distance 0.5-150 meters



unit and the leveling bucket was presented in this study. The laser controlled leveling system was integrated with low-sized and medium-sized tractors (30-60 hp) to conduct land leveling experiments. The experimental results showed that the accuracy of land leveling using the laser controlled system was ~ 3 cm and the efficiency was estimated at ~ 0.2 hectare per hour. The efficiency of land leveling was investigated. It was limited by such factors as the even level of the field, the size of the leveling bucket, the proficiency of the driver. Most importantly, strategy for land leveling was complex to achieve an accurate route due to the rough conditions of the field. In the practices of land leveling, a simple circling or quasi-circling route might be suitable not only for the efficiency but for the operation of the driver.

The laser controlled leveling system could be constructed at low cost. Therefore, the lower-cost laser controller leveling system might be very attractive to replace some commercial products with similar accuracy level but at higher cost. Certainly, the users need to trade-off the efficiency with the cost of laser controlled leveling system. The advanced and appropriate laser controlled leveling technology would open a great potential for extension in precision irrigation and farmland management in less developed regions.

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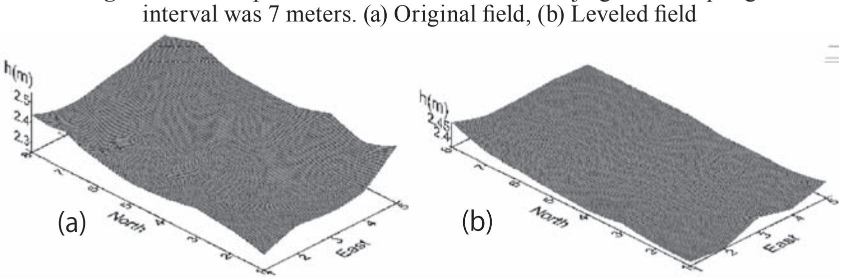
Fig. 7 Terrain maps of the 35 m x 60 m field at Beijing. The sampling interval was 7 meters. (a) Original field, (b) Leveled field



Chickpea Threshing Efficiency and Energy Consumption for Different Beater-Contrbeater Combinations

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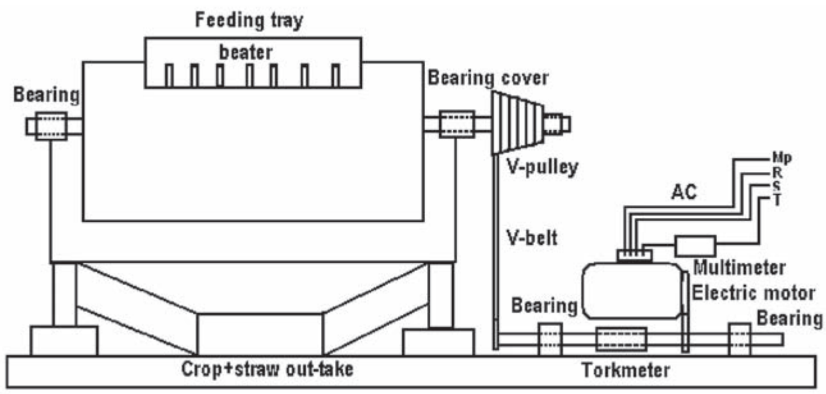
Abstract

Threshing efficiency, specific energy consumption and power requirements of different beater (drum) and contrbeater (concave) types in chickpea threshing were investigated in this experimental research. The purpose was to define the effect of beater and contrbeater types made of different materials on the threshing of various chickpea varieties. The trials used six beater-contrbeater combinations of three types of beaters (spike-tooth, lama (flat)-tooth and peg-tooth) and two types of contrbeaters (PVC and chromium) with a stationary thresher. Rotational speed of threshing drum, contrbeater clearance and feeding rate were 12.5 m/s, 25 mm and 720 kg/h, respectively. In order to determine the appropriate peripheral speed, contrbeater clearance and feeding rate serial preliminary experiments were conducted. Five rotational drum speeds (19.0, 14.5, 12.5, 10.50 and 8.0 m/s), five contrbeater clearances (150, 200, 250, 300 and 350 mm) and four feeding rates (360 kg/h, 540 kg/h, 720 kg/h, and 900 kg/h) were selected for the preliminary studies. According to the results of these experiments and observations during these trial periods, the appropriate values were chosen. Three chickpea varieties (K üsmen, Köylü and Akçin) were also selected because these chickpea varieties are largely cultivated in all regions of Turkey. The results showed that threshing efficiency significantly changed with chickpea variety while the specific energy consumption and power requirement was slightly affected by the beater-contrbeater combination and chickpea variety. The highest threshing efficiency

Fig. 1 Schematic presentation of the threshing unit



and appropriate specific energy consumption were achieved with peg-tooth beater - chromium contrbeater, spike-tooth beater - PVC contrbeater and lama-tooth beater - PVC contrbeater combinations with values of 67.06 %, 0.71 kWh/t, 89.11 %, 0.60 kWh/t, 95.29 % and 0.68 kWh/t for Küsmen, Köylü and Akçin varieties, respectively.

Introduction

Chickpea (Cicer arietinum) is a ready source of protein for the diet of masses in many Asian countries. It is cultivated as a winter crop in the tropics and a spring or summer crop in the temperate climate. The annual world production of chickpea is about 7 million t of dry grain from an area of 10 million ha. Some 85 % of production stems from South Asia but the cropping area extends westwards from Afghanistan, through West Asia and the Mediterranen basin into Ethiopia and East Africa, the Americas and Australia. (Anwar and Gupta, 1990; Anwar et al., 1991). Besides, many varieties of chickpea are largely cultivated in all regions of Turkey. Chickpea is mainly used for human food in Turkey. It contains high levels Ca, P, Fe and A, B, C vitamins and the protein content ranges from 18 to 31 %. Because of its high histidine, it has a vital role in children feeding, (Zeren and Isik, 1991).

During recent years greater interest has been given to the cultivation of chickpea because of its deictic chromium, industrial, agricultural and medical importance. However, during harvesting and threshing, there is a significant product losses. Particularly, high threshing loss makes this a very significant problem in Turkey. Many different inappropriate mobile and stationary threshers and threshing units are used for threshing chickpeas in Turkey. These decrease the threshing efficiency and increase specific energy consumption and power requirement. Therefore, a stationary chickpea-threshing unit was designed, manufactured and used in this experiment to determine the most productive beater-contrbeater combinations in chickpea threshing.

Materials and Methods

A stationary chickpea threshing unit seen in **Fig. 1** was designed and manufactured for the purpose of threshing trials. The length of the contrbeater was 0.9 m. The diameter and length of threshing drum were 0.9 m and 0.38 m, respectively. The concave clearance, peripheral speed and feeding rate were fixed at 25 mm, 12.5 m/s and 720 kg/h for all combinations of beater and contrbeaters. Two concave types, made of PVC and chromium, and spike-tooth, lama (flat) -tooth, peg-tooth beaters were selected for the research (**Figs. 2**, **3** and **4**). Preliminary experiments included six combinations; spike-tooth beater -

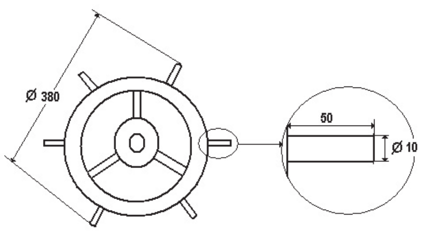


Fig. 2 Dimensions of the spike-tooth beater (all measurements are mm)

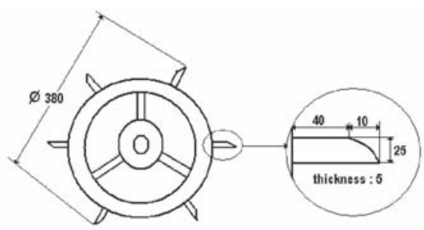


Fig. 3 A view of the lama (flat)-tooth beater

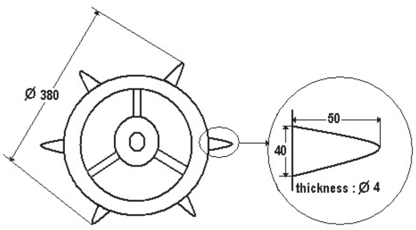


Fig. 4 The peg-tooth beater

Type	AGM 132 M 6a
Voltage-Current	Δ380 V, 9.4 A
Power	4 kW
Cos φ	0.81
Rotation	935 rpm
Frequency	50 Hz
Transmission to beater	96 %

Table 1 Technical specification of the electric motor

Beater-contrbeater combination
Sp-t-PVC: Spike-tooth-PVC combination
Sp-t-cr: Spike-tooth-cromium combination
La-t-PVC: Lama-tooth-PVC combination
La-t-cr: Lama-tooth-cromium combination
Pe-t-PVC: Peg-tooth-PVC combination
Pe-t-cr: Peg-tooth-cromium combination

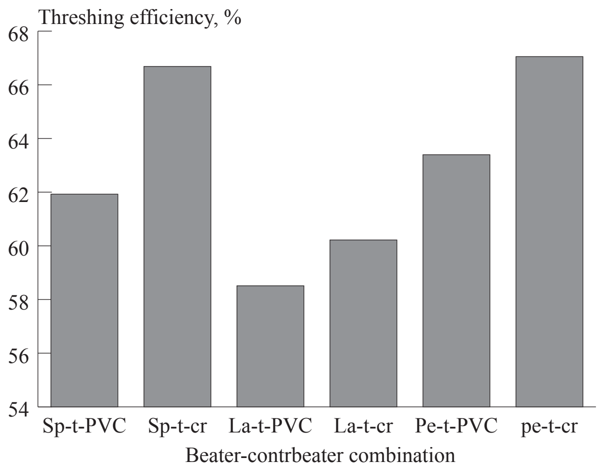


Fig. 5 Threshing efficiency of different beater-contrbeater combinations for Küsmen chickpea variety

PVC contrbeater, spike-tooth beater - chromium contrbeater, lama-tooth beater - PVC contrbeater, lama-tooth beater - chromium contrbeater, peg-tooth beater - PVC contrbeater and peg-tooth beater - chromium contrbeater. In order to determine the appropriate peripheral speed, contrbeater clearance and feeding rate, serial preliminary experiments were conducted. Five peripheral speeds (19.0, 14.5, 12.5, 10.50 and 8.0 m/s), five contrbeater clearances (150, 200, 250, 300 and 350 mm) and four feeding rates (360 kg/h, 540 kg/h, 720 kg/h, and 900 kg/h) were used for the preliminary studies. According to the results of these experiments and observation during these trial periods, the appropriate values were determined. Three chickpea varieties such as Küsmen, Köylü and Akçin were also selected for this research because of the fact that these chickpea varieties are largely cultivated in all regions of Turkey. It was harvested by the conventional method. The moisture content of the grain, head and straw was determined by oven-drying method (ASAE, 1984). The average moisture contents of (grain) seeds, head and stalk (straw) were 7.5-8.5 %, 11-13 % and 10-12 % w.b., respectively for all chickpea varieties. The threshing drum was powered by an electric motor, which was placed on a special frame. A belt-pulley system provided the movement transfer between the threshing beater and the motor (**Fig. 1** and **Table 1**). Material was loaded on a flat surface and fed into the hopper manually. Moment Measuring Device (Torquemeter) and Multi-Measuring Device (Multimeter) were used to measure the rotating moment (**Fig. 1**). The power requirement was calculated by using the formula given by Yavuzcan et al. (1987) and Tezer et al. (1993). Consumed specific energy values for threshing 1 ton of stalk product were obtained by means of mean power values. Unthreshed seeds were separated from pods and the collected seeds were weighed after threshing and cleaned by hand to determine the threshing efficiency as a percentage of total seeds collected (Sharma and Devnani, 1980;

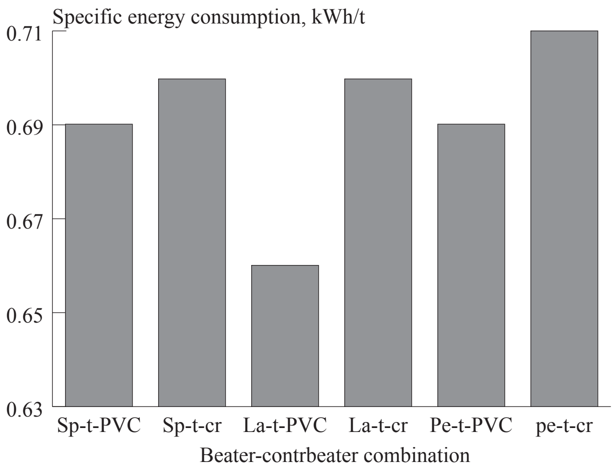


Fig. 6 Specific energy consumption of different beater-contrbeater combinations for Küsmen chichpea variety

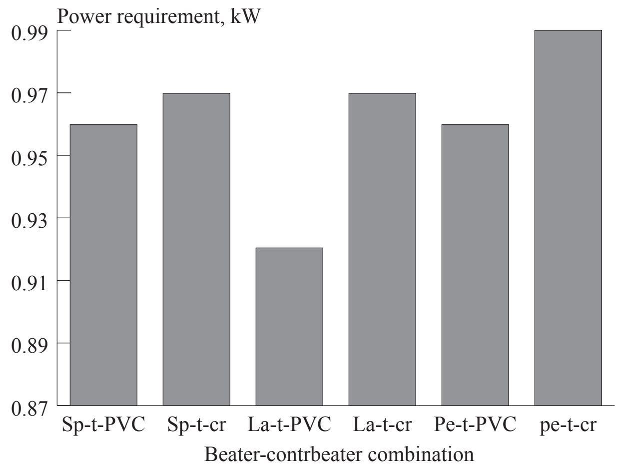


Fig. 7 Power requirement of different beater-contrbeater combinations for Küsmen chichpea variety

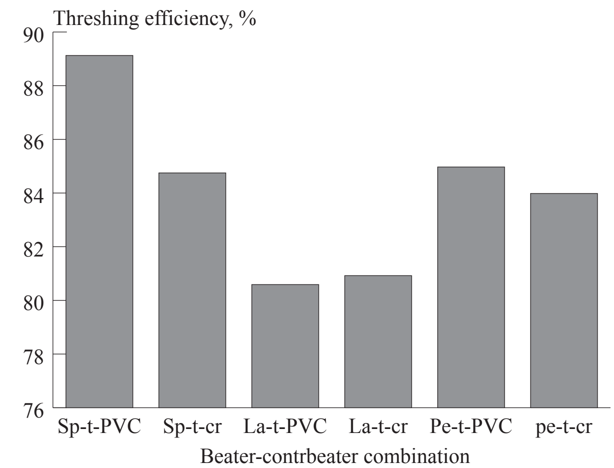


Fig. 8 Threshing efficiency of different beater-contrbeater combinations for Köylü chichpea variety

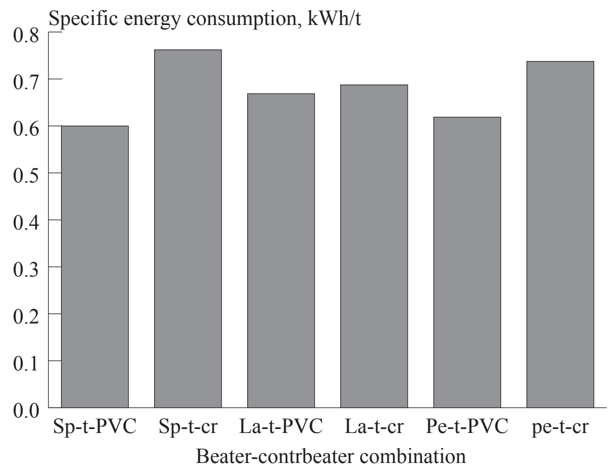


Fig. 9 Specific power consumption of different beater-contrbeater combinations for Köylü chichpea variety

Bhutta et al., 1997; Sessiz, 1998).

Results and Discussion

During the course of the trials, threshing efficiency, specific energy consumption and power requirement were recorded for six different beater - contrbeater combinations (spike-tooth beater - PVC contrbeater, spike-tooth beater - chromium contrbeater, lama-tooth beater-PVC contrbeater, lama-tooth beater-chromium contrbeater, peg-tooth beater-PVC contrbeater and peg-tooth beater-chromium contrbeater) and three chickpea varieties (Küsmen, Köylü and Akç in). Each datum given in figures is an average of three observations. The results regarding threshing efficiency, specific power consumption and power requirements for each beater-contrbeater combinations are presented separately in this part. These values are given in **Figs. 5-7** for Küsmen. From these figures, it is observed that there is negligible difference between beater-contrbeater combinations for specific energy consumption and power requirement while the important threshing efficiency occurs depending on the combinations. The minimum and maximum threshing efficiency were determined from lama-tooth beater - chromium contrbeater and peg-tooth beater - chromium contrbeater combinations with 58.55 % and 67.06 %, respectively. In addition, the threshing efficiency of chromium contrbeater was found higher than PVC contrbeater for all experimental combinations of Küsmen variety.

The experimental results related to Köylü chickpea variety are seen from **Figs. 8-10**. The lowest values of threshing efficiency, specific energy consumption and power requirement are 80.63 %, 0.60 kWh/t and 0.83 kW while the highest are 89.11%, 0.74k Wh/t and 1.06 kW, respectively for various beater-contrbeater combinations. Data gathered from trial of Köylü chickpea variety shows that the PVC contrbeater is more appropriate than chromium contrbeater.

Figs. 11-13 presents threshing ef-

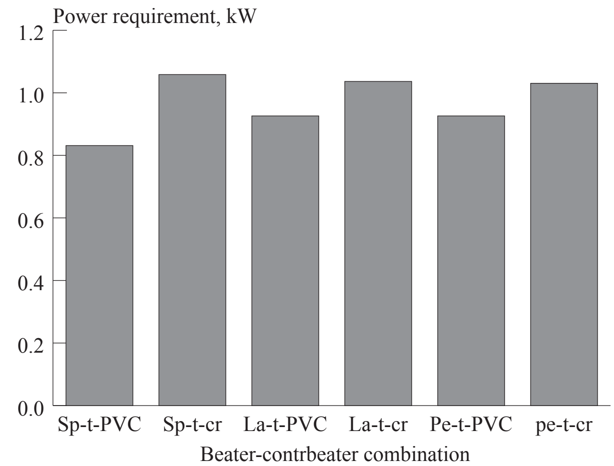


Fig. 10 Power requirement of different beater-contrbeater combinations for Köylü chichpea variety

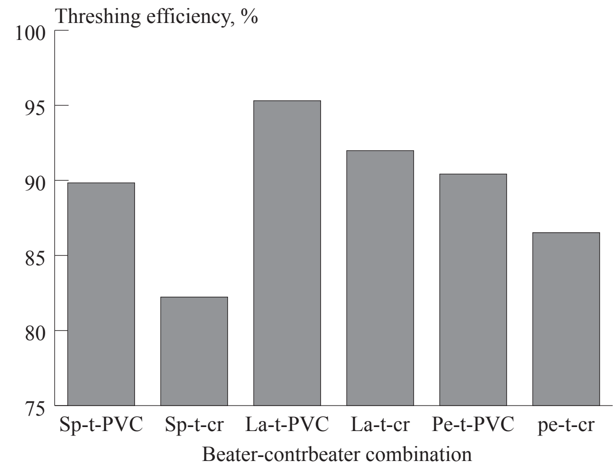


Fig. 11 Threshing efficiency of different beater-contrbeater combinations for Akçin chichpea variety

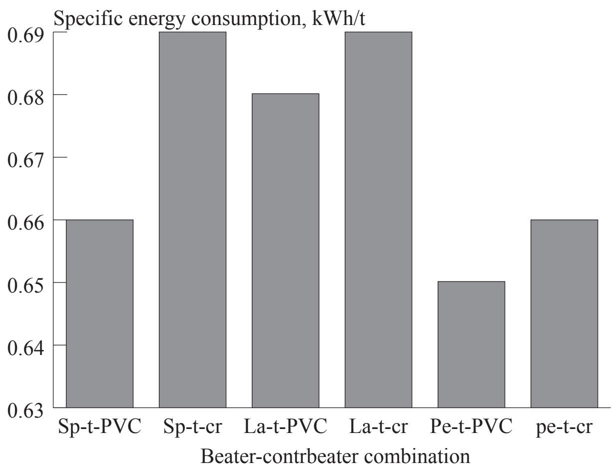


Fig. 12 Specific power consumption of different beater-contrbeater combinations for Akçin chichpea variety

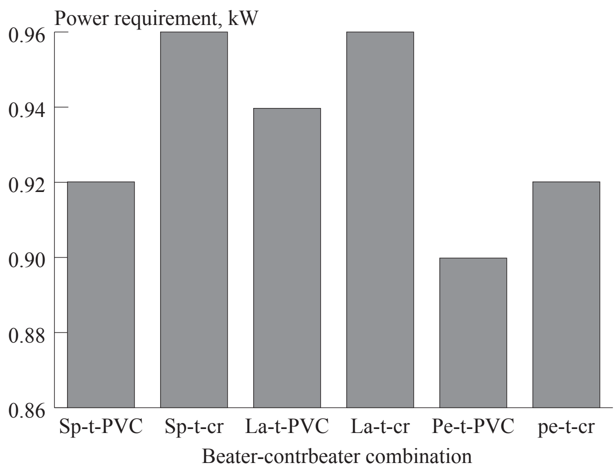


Fig. 13 Power requirement of different beater-contrbeater combinations for Akçin chichpea variety

ficiency, specific energy consumption and power requirement at different beater and contrbeater combinations of chickpea Akçin variety. The highest threshing efficiency, along with less specific energy consumption and power requirement were obtained for Akçin variety when compared with Küsmen and Köylü. Threshing efficiency was in the range of 82.31 % to 95.29 % for Akçin.

Conclusions

It is obvious from **Figs. 5-13** that the chickpea varieties have significant effect on threshing efficiency. It can be said that this results from the physical and mechanical specification differences between varieties of selected chickpeas. In addition, there is negligible difference between beater - contrbeater combinations for specific energy consumption and power requirement. This means that the most appropriate beater - contrbeater combinations must be selected depending on the threshing efficiency of chickpea varieties.

As a result, peg-tooth beater - chromium contrbeater, spike-tooth beater - PVC contrbeater and lama-tooth beater - PVC contrbeater combinations are recommended for Kü smen, Köylü and Akçin chickpea varieties, respectively. Threshing efficiency, specific energy consumption and power requirement at these combinations are 67.06 %, 0.71 kWh/t, 0.99 kW, 89.11 %, 0.60 kWh/t, 0.83 kW, 95.29 %, 0.68 kWh/t, 0.94 kW for Küsmen, Köylü and Akçin, respectively.

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Rotary Tiller Blade Surface Development

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Abstract

Three different rotary tiller blade types, viz. C_L-type (local), L-type and C_J-type (Japanese) were selected for surface development using the Bezier approach. Multiple Bezier surface patches were generated and joined end to end to form complete a blade surface. The absolute dimensional error between generated and real blade surfaces for all the three blades in x, y and z coordinates was below 3.7, 3.2 and 1.6 respectively. Software to visualize the three dimensional shape of rotary tiller blade, which allows the user to alter the control surface, was developed.

Introduction

Agricultural implement design is hindered by lack of adequate analytical methods, thus many implements are designed empirically. True engineering design cannot be achieved until analytical relationships based on scientific principles are available. The goal of tool design is to optimize the function, efficiency and economy of the tillage process. In the past, much attention has been directed to tillage tool shape as related to energy requirements and final soil conditions. The investigations were concerned not only with macroshape but also with the boundary or cutting edge of the tool. Since the area of the cutting edges of a tool is much smaller than the area of the surface, emphasis was also placed on the surface over which the soil moves (Ros et al., 1995).

Computer graphics techniques have been applied to some soil working tools such as the mould board plough (Richey et al., 1989) and rotary tiller blades (Kinzel et al., 1981 and Singh, 1999). Thomas Jefferson (1799) developed a method to accurately describe the surface of a mouldboard plough. It was a physical method that can be used in constructing a plough. He used two straight lines as fixed directives while a third line moved and rotated in a fixed plane. Jefferson's method was practical; however, it was purely based on intuition. White (1918) analysed a number of ploughs using Jefferson's method. He established equations to derive the surface in the Cartesian coordinate system. He demonstrated that an existing plough shape could be mathematically represented.

Graphical description of plough shapes have been developed by various researchers including White (1918) and Ashby (1931) as described by Gill and Vandenberg (1967). They used graphical methods to define shape and to establish design equations. A Graphical method to establish the shape of an existing plough was to use a pair of parallel vertical surfaces with coinciding grid holes. The surfaces established the y-z plane while the horizontal plane was the x-y plane. The plough whose shape was to be determined was placed in front of the vertical gridded surfaces. A measuring rod was inserted through the grid holes until it touched the plough surface. This established the x measurement while the location of grid hole determined the y and the z dimensions. Using this data, a two dimensional representation of the surface was plotted in the x-y plane by plotting the constant z value grid lines. Soehne (1959) used an optical means to expedite this method. He projected a light through a slit, either horizontal or vertical, on to the painted plough surface. A camera was used to record the reflected light. A series of photographs was taken by moving the plough to different positions.

Ros et al. (1995) identified and defined the geometrical parameters of tillage tools, from a simple blade to mouldboard surfaces, and developed a mathematical representation for a tool surface. He also developed a general approach to tillage tool system design in relation to energy and soil properties. Cracium and Leon (1998) presented a complete methodology for analytically solving the entire problem related to mouldboards with cylindroidal geometry. He gave a mathematical equation of the mouldboard and the working surface of the plough bottom in Cartesian coordinate system.

The premises of this paper centers around generation of three dimensional rear surfaces of C_L-shape, L-shape and C_J-shape blades using multiple patch technique, such that the error between the computer generated surface and the real surface is minimised.

Computer Graphics

There are many ways to define a bicubic parametric surface. The Bezier-Bernestein form is of special interest. Bezier surface can be generated in patches (Asthana and Sinha, 1996). A Bezier surface patch and its control points are created using isoparametric lines. Continuity between two patches can be achieved by taking the corner points common between two consecutive patches. In this way, the error in modelling of Bezier surface can be minimized to a large extent. Below is a brief discussion on the Bezier Curve and subsequent development of the Bezier surface. The reader is referred to Hill (1990), Plastock and Kalley (1986) and Asthana and Sinha (1996) for a complete discussion.

The Bezier Curve

The Bezier curve, p(t), based on the (L+1) control points, **Fig. 1a**, p_0, p_1, p_2, ... , p_L is given by

$$p(t) = \sum_{i=0}^{L} p_i B_i^{\,L}(t) \quad \text{.....(1)}$$

where the function $B_i^L(t)$ are known as Bernstein polynomials. The i^{th} Bernstein polynomial is defined as:

$$B_i^{\,L}(t) = {}^{L}C_i (1-t)^{L-i} t^i \quad \text{.....(2)}$$

where ${}^{L}C_i$ is the binomial coefficient function, the number of ways of choosing 'i' items from a collection of 'L' items. It is given by

$${}^{L}C_i = \frac{L!}{i!(L-i)!} \quad \text{.....(3)}$$

and 0 otherwise.

One can write a single equation for each variable x, y and z to represent a 3D curve as follows:

$$x(t) = \sum_{i=0}^{L} x_i B_i^{\,L}(t) \quad \text{.....(4)}$$

$$y(t) = \sum_{i=0}^{L} y_i B_i^{\,L}(t) \quad \text{.....(5)}$$

$$z(t) = \sum_{i=0}^{L} z_i B_i^{\,L}(t) \quad \text{.....(6)}$$

The behaviour of the Bezier curve is governed by the interpolating functions $B_i^L(t)$ (Plastock and Kalley, 1986). Bezier curves are quite suitable for interactive graphics and are used in the automobile and aviation for modelling of surfaces.

The Bezier Surface

The methods stated above can be generalized to describe curved surfaces. To describe a surface, a grid of control points (x_{ij}, y_{ij}, z_{ij}) is needed. Stepping through 'i' moves one direction on the grid while changing 'j' moves in the other direction. Such a grid can be used to define patches which will fit together to form a smooth surface.

The formulation of the Bezier curve extends easily to describe three-dimensional surfaces by generating the Casteljau product of two curves. Two similar blending functions are used, one for each parameter.

$$p(s,t) = \sum_{i=0}^{L}\sum_{j=0}^{M} p_{ij} B_i^{\,L}(s) B_j^{\,M}(t) \quad \text{......(7)}$$

The Bezier surface with (L+1) x (M+1) control points can be shown as **Fig. 1b**, arranged in a mesh. Adjacent control points are connected with lines in order to show the mesh. The surface itself is shown by drawing two sets of curves. One set holds the 's' parameter constant and allows 't' to range from 0 to 1, the other set holds 't' and varies 's'. These curves of constant 's' and 't' are, in fact, Bezier curves. The coordinates values for points on the surface of a patch are given by:

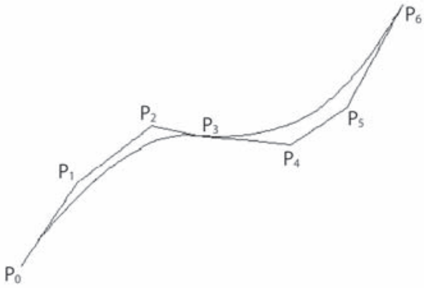

Fig. 1a A bezier curve based on seven (6+1) control points

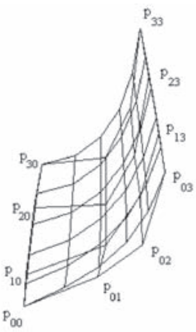

Fig. 1b A bezier surface patch based on 4x4 (3+1)x(3+1) control points

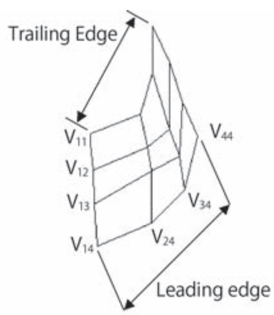

Fig. 2 Control points of developed blade at zero degree orientation in single patch (GS methods)

$$x(s,t) = \sum_{i=0}^{L}\sum_{j=0}^{M} x_{ij}B_i^{\ L}(s)B_j^{\ M}(t) \ldots\ldots(8)$$

$$y(s,t) = \sum_{i=0}^{L}\sum_{j=0}^{M} y_{ij}B_i^{\ L}(s)B_j^{\ M}(t) \ldots\ldots(9)$$

$$z(s,t) = \sum_{i=0}^{L}\sum_{j=0}^{M} z_{ij}B_i^{\ L}(s)B_j^{\ M}(t) \ldots..(10)$$

There are two parameters, which specify the position on the surface patch, s and t. Just as for curves, each varies from 0 to 1.

Generating Blade Surface

Sixteen control points were measured (Singh, 1999) on a pre-selected portion of the blade surface, **Fig. 2**, such that there were four points on each x-y plane. In this method referred to henceforth as GS method (Singh, 1999) four x-y planes separated by known Z-distance (along z-axes) were selected. The cutting edge was developed from the (V_i, 4) points lying on the vertical plane V_i. Point '4' lies on the cutting edge while point '1' was the extreme trailing point. Points '2' and '3' were in between '1' and '4' but on V_i plane. In the GS method it was apparent that, to cover a surface as large as a rotavator blade and especially the one whose surface in three-dimensional space keeps on articulating, would yield a Bezier developed surface with very large percentage of error.

In order to develop a Bezier surface of the complete blade such that it comes very close to the real blade surface, one has to cover the entire blade surface in patches- each patch having sixteen control points. The method to measure control points in each patch need not have the constraint of four x-y planes of the GS method. However, in this method four control points were taken on the leading edge and four on the trailing edge and the rest were selected in between the leading and trailing edge in each patch. Two flat boards 28 x 23 x 1 cm and 23 x 17 x 1 cm thick had mesh of holes of 2-mm diameter. The mesh size was 5 x 5 mm. They were fitted perpendicular to each other and were aligned with each other's meshing (**Fig. 3**). One of the flat-board 28 x 23 x 1 cm referred to as base plate had mesh in x and y axis and the other flat-board 23 x 17 x 1 cm referred to as vertical plate had mesh in y and z axis. A hole of 12.7 mm (1/2") was drilled for mounting the blade on the base plate. The center of the hole on the rear surface of the blade, was considered the origin of blade coordinate system. The blade was bolted (in the lower hole of the blade) on the base plate (**Fig. 3**). The orientation of the blade was taken as the angle that the line passing through the origin and parallel to the lower edge in the flat length of blade made with the x-axis of the base plate. Four identical needles (**Fig. 3**) 2 mm in diameter and 20 cm high were used. The control points all over the blade surface were selected and needles were inserted in the holes at desired location. The vertical plate was needed to measure the desired control points on that portion of the rear surface of the blade that was nearly vertical and/or control points that were difficult to measure from the base plate. This method referred to as the VS method (Singh, 2001) had the advantage that the entire blade surface was covered in four patches (**Fig. 4**) and it consumed less time in measurement of control points. End to end points, where patches were joined, were common to both the patches. Thus, there were fifty-two control points for each blade. The three-dimensional blade surface developed for C_L-type, L-type and C_J-type are shown in **Fig. 5a**, **5b** and **5c**.

Errors in Generated Surface

The error in developing the blade surface occurs because the approximated Bezier points do not match control points on the actual blade surface except at four corner points in a patch. The error in the developed blade surface was found at each node of the control polygon with corresponding node in the approximated Bezier surface. While computing the error, the number of nodes in the approximated Bezier

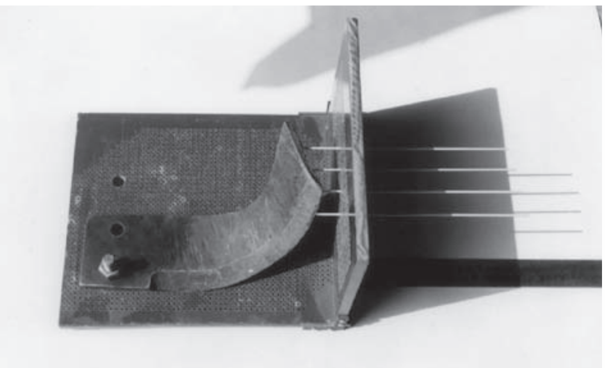

Fig. 3 Schematic setup for measurement of blade coordinates

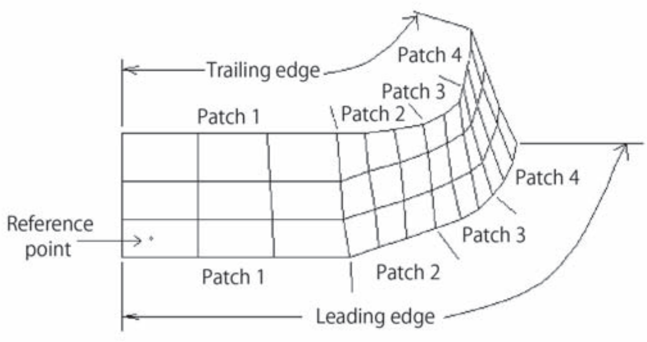

Fig. 4 The complete blade surface generated by joining four patches of control points

surface were maintained the same as that in the control polygon, i.e. 4 x 4 mesh size. The reason for having equal mesh size was to have one to one correspondence between the control polygon and the Bezier polygon. Otherwise it was difficult to make a comparison. The error at the four corners in each patch was zero because the nodes at these corners remain invariant for both the control polygon and the Bezier approximated surface.

The absolute dimensional error between the generated surface and real surface was below 0.12, 0.5 and 0.8 mm in x, y and z coordinates, respectively, for the C_L type blade. The absolute dimensional error for the L type and C_J type blade was below 2.5, 3.2, 1.6 mm and 3.7, 1.0, 1.6 mm, respectively, for x, y and z coordinates.

Comparing the Errors using GS and VS Method for C Shaped Blade

The error in developing the C shaped blade surface for zero degree orientation using the GS and VS method with the reference point stated earlier was found. In the GS method the error in the x-coordinate of the developed blade surface for all the vertical planes was reported below 5.0 percent. It was reported below 6.0 percent for the z-coordinate and zero for plane 1. However, for point (1, 4) the error in the y-coordinate was reported to be 48.2 percent.

The maximum percentage error in developing the blade surface using the VS method at zero degree orientation was 1.19, -4.94 and -8.02 percent for x, y and z coordinates, respectively.

In the GS method, the control points, for developing a blade surface were measured at 10 and -10 degrees orientation and the maximum error in developing blade surface was found to be 144.4 and 227.2 percent, respectively. However, there was no need to measure control points at different orientations. Coordinate transformation (rotation about reference point) could be applied to control points at zero degree orientation.

In the GS method only a portion of the working surface of the blade was covered in a single patch, whereas in the VS method the entire blade surface was covered using four patches of control points for developing surface. Thus, the error could not be compared point by point. However, the overall error was compared.

Variation in Error Using GS and VS Techniques by Generating the Same Surface Using Three Patches

The working surface of the C-type blade at zero degree orientation was divided into three patches. Control points were measured for each patch using the GS and VS method. The reference point for measuring coordinates in both cases was the same, viz. center of one of the holes for mounting the blade. It was difficult to keep same size of each patch in the GS and VS techniques because control points in the GS method had a constraint that they should lie on x-y plane for constant z coordinate.

Irrespective of the methods, the error in general remained high

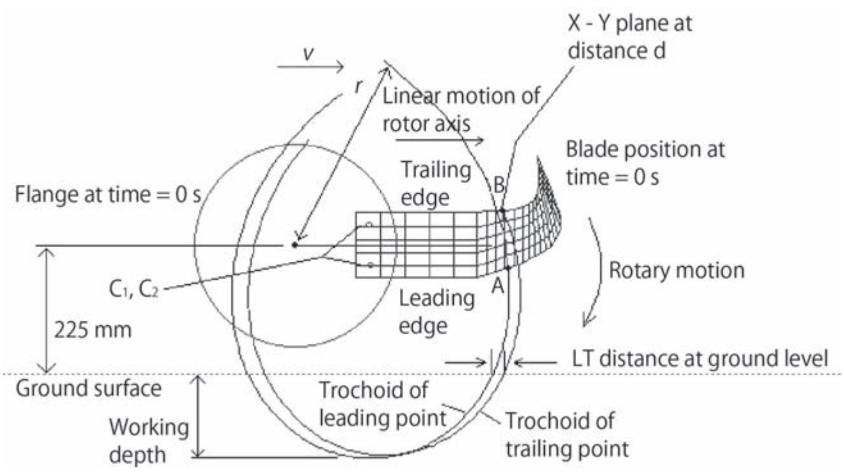

Fig. 6 Trochoids of leading and trailing points (A and B) of a C-type blade with mounting bolts C_1 and C_2; velocity ratio 4.97; travel speed (v) 3.50 km/h; angular velocity 23.03 rad/s; rotor speed 220 rpm; blade orientation angle 0 degree; depth 30 mm; rotor radius 210 mm

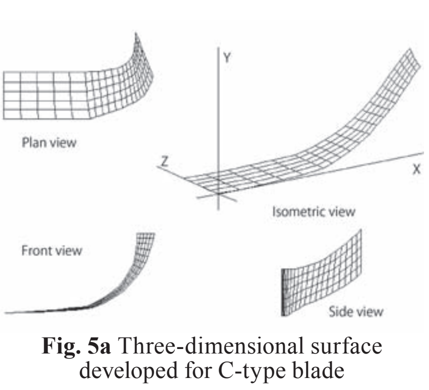

Fig. 5a Three-dimensional surface developed for C-type blade

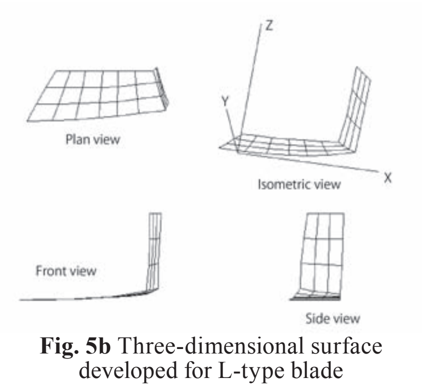

Fig. 5b Three-dimensional surface developed for L-type blade

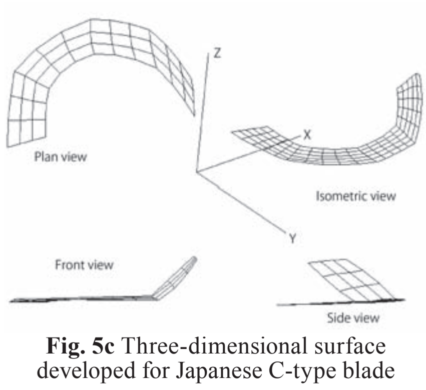

Fig. 5c Three-dimensional surface developed for Japanese C-type blade

where blade curvature was least, e.g. in patch one. This occurred because of the very small magnitudes of control points. The maximum percent error in patch one along x, y, z coordinate was 2.03, 9.97, -7.41 using GS technique and 0.78, -4.94, -9.43 using VS technique. It stood at 1.17, 6.17, 2.4 (using GS method) and 1.16, 3.97, 2.64 (using VS method) in patch two and 0.98, -5.21, -2.96 (using GS method) and 0.48, -1.98, 1.48 (using VS method) in patch three. Since the reference point was not the same in the GS and VS method it is worthwhile to look for absolute errors. The magnitude of absolute errors was quite small, e.g. in patch two along x, y, z coordinate it was 1.8, 1.7, 1.4 mm in the GS method and 1.4, 1.5 and 2.1 mm in the VS method.

Kinematics Analysis

Kinematics analysis, as shown in **Fig. 6**, effectively made for soil tool interaction studies. Detail is beyond the scope of the present study. Also, the method can be generalized for designing and developing any part of agricultural implement.

Conclusions

Using computer graphics Bezier surfaces of the rear surface of blades were generated. The VS method was more suitable for generation of blade surface than the GS method as it reduced the error. The error in generating a surface was considerably reduced by joining multiple Bezier surface patches. The treatment can be extended, with ease, to any shape of a rotary tiller blade.

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Present Status and Future Scope of Mechanization of Horticultural Crops in Mountains

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Abstract

Horticulture plays an important role in the economy of the Himachal Pradesh because of favourable climatic conditions. The total production of horticultural crops, i.e. fruits and vegetables in the state is about 447.68 thousand-tonnes and 640 thousand-tonnes from cultivated area of 207.2 thousand-hectare and 41.8 thousand-hectare, respectively. Apple and citrus are major fruit crops and contribute about 59.9 % area and 90.8 % production. Among the vegetables, potato and pea cover nearly 50.0 % of the area and 35.54 % of the vegetable production. Although area and production of horticultural crops are increasing at a fast rate, all the operations performed in cultivation of these crops are being done manually with conventional tools, which involves quantum of labour force and drudgery. This paper discuss the economic importance of horticultural crops, their cultivation practices, present status and future needs of mechanization to increase production with reduced cost of production and drudgery. This paper also discusses the types of machines required for different operations particularly for major crops in fruits and vegetables suiting to mountain region.

Introduction

Himachal Pradesh is located on a sloping terrain of the great Himalayas, with snow clad mountains, rolling hills and valleys. The state is situated between 30.3 and 33.30 North Latitude and 75.3-79.00 East Longitude. The state is broadly classified into four agro-climatic zones, viz. sub-mountain low hills sub-tropic zones (365-650 m above m.s.l.), mid-hills sub-montane zone (651-1,800 m above m.s.l.), high hill temperate wet zone (1,801-2,200 m above m.s.l.) and high hill temperate dry zone (> 2,200 m above m.s.l.). Each agro-climatic zone can be further divided in to various micro-agro-climatic zones due to great variation in slope, topography, soil and water availability. Numerous micro-agro-climatic zones provide favourable environment for raising almost all types of agricultural and horticultural crops. The suitability of horticultural crops in different agro-climatic zones is given in **Table 1**.

India with production of more than 38 million-tonnes of fruits and 75 million-tonnes of vegetables including potato, is the second largest producer of fruits next to Brazil and of vegetables next to Chiana. India is also the largest producer of ginger and turmeric and accounts for 65 % and 76 % respectively of the world production (Singh et al., 1999). The total production of horticultural crops, i.e. fruits and vegetable, in the state is about 447.68 thousand-tonnes and 640 thousand-tonnes from cultivated area of 207.2 thousand-hectare and 41.8 thousand-hectare, respectively. Due to this, horticulture plays an important role in the economy of the state. Apple and citrus are major fruit crops and contribute about 59.9 % area and 90.8 % production. Among the vegetables, potato and peas cover nearly 50.0 % of the area and 35.54 % production. There are also some indigenous varieties of different horticultural crops, which are among the best in national as well as international markets. For example, Kufri (Pahari) variety of potato and tea of kangra. Although the area and production of horticultural crops is increasing at a fast rate, the level of mechanization of different operations for the horticultural crops is very low due to small holdings and traditional modes of cultivation. There is tremendous scope of mechanization of different operations for horticultural crops. The scenario of fruit and vegetable production in Himachal Pradesh and India is given in **Table 2**.

Economic Importance of Different Crops

The economic importance of different crops is judged on the basis of area of cultivation and production of the crop. The temperate, tropical and sub-tropical fruits are grown throughout the state. Area and production of major horticultural crops in Himachal Pradesh is given in **Table 3**.

Cultural Practices and Level of Mechanization

Field Preparation

For raising crops, a well-ploughed bed is the pre-requisite for all crops. Seed-bed preparation for nursery raising and other fruit and vegetable crops is the most time consuming and drudgery oriented operation and performed by manual or bullock power (**Fig. 1**). Mostly the fields are prepared by ploughing with bullocks. The spade is used for this purpose manually. The ridge and furrow formation is also accomplished manually by spade.

Propagation

The fruits and vegetables are propagated by different techniques as discussed below.

Apple is mainly propagated by grafting and budding with knife. The rootstocks are raised from the seeds of crab apple or commercial cultivars. The seeds after stratification are sown at a distance of 7-10 cm in rows 30 cm apart. After one year the suitable seedlings are used for grafting/budding. The clonal rootstocks are propagated by mound or stool layering. The grafted plants are ready for planting in about one year.

All the commercial citrus fruits grown in Himachal Pradesh are generally propagated through 'T-budding'. Jambhiri commonly known, as jatti khatti is the common rootstock used for the propagation of these fruits. One year old seedlings are transplanted in the field.

The mango seed (stones) are sown in the nursery beds at a spacing of 15-20 cm distance. The beds are well prepared and manured with FYM. The beds are irrigated immediately after sowing the stones. The seedlings are ready for grafting when they attain 45 cm height and thickness of 0.75 to 1.5 cm. The grafted plants are ready for planting in about a year. Air layering (gootee) is used commercially for raising litchi plants. The plants prepared by this method are ready within a year. Walnut is propagated either by seed or by vegetative method. In the second year, the seedlings are ready for transplanting. One year

Table 1 Suitability of horticultural crops in different agro-climatic zones

Zones	Suitable fruit crops	Suitable vegetable crops
Sub-tropical sub-montane low hills (Zone 1)	Mango, citrus, litchi, loquat, guava, papaya and low chilling cultivars of peaches and plums	Brinjal, lady's finger, pea, tomato, potato, beans, onion and cucumber
Sub-temperate and sub-humid mid hills (Zone 2)	Stone fruits, pome fruits, walnut, lemon, galgal, pomegranate, olive, kiwi fruits etc.	Tomato, beans, capsicum, ginger, peas, potato and cucumber
Wet-temperate high hills (Zone 3)	Pome fruits	Pea, bean, cabbage, cauliflower, radish, turnip, carrot, potato and sugarbeet
Dry temperate high hills and cold deserts (Zone 4)	Apple, pear, nuts, prunes and grapes	Potato, pea, cole crops, turnip and onion

Table 2 Senario of fruits and vegetables production

Crop	Production in million tonnes	
	India	Himachal paradesh
Fruits	38	0.45
Vegetables	75	0.64

Fig. 1 Traditional method of seedbed preparation

old seedlings are used as rootstock for grafting/budding.

Plums, peaches and almond are generally grafted on wild peach rootstock whereas apricots are grafted on wild apricot seedling rootstock. One year old seedlings are used for grafting/budding. Pecan-nut is generally propagated through grafting/budding on one-year old seedlings but the vegetative propagation has been less efficient in pecan when compared with other common fruits.

Nursery of tomato, cabbage, cauliflower and brinjal is raised and the seedlings are transplanted manually on ridges at required spacing. Nursery of capsicum, chillies and onion is raised and the seedlings are transplanted on flat or ridges. The seeds of radish and carrot are drilled on ridges.

Planting

The pits for planting the tree sampling are dug manually with a spade (**Fig. 2**). On an average, a man can hardly dig 3 to 4 pits 1 x 1 x 1 m in a day. Pits for erecting bower or trellises for kiwis are dug manually and wires of bower or trellises are also drawn manually. The size of the pit and spacing of planting different fruit crops are given in **Table 4**.

Fig. 2 Pit digging with spade

The planting practices of different vegetables and spice crops are given below in **Table 5**. The garlic cloves are planted in level fields at a seed rate of about 5.5-7.0 q/ha. Rhizome of turmeric and ginger are planted on raised beds at a seed rate of about 20-25 and 18-22 q/ha, respectively.

A nursery is used to start some vegetable crops and from which they are transplanted manually, consuming a lot of labour and drudgery. The planting practices for vegetable crops (transplanting) are given in **Table 6**.

Sowing/Dibbling

Most of the vegetable crops are sown on ridges manually and ridges are prepared manually with spade or kudali. Sowing and dibbling of all vegetables crops are done manually which consume a lot of labor, ultimately increasing the cost of operation.

Basin Preparation and Fertilizer Application

In orchards, plants need well-ploughed basins. In fruit crops, basin preparation is mostly done with a spade, which is a very labour intensive and drudgery-oriented operation. On an average, a man can prepare 2.2 basins per hour of 1.5 m radii in mango crops (Anonymous 2004).

Weeding and Earthing up

Earthing up operation in the case of potato and other ridge sowing vegetable crops is done manually with a spade. Frequent weeding is required in vegetable crops. Weeding is done manually with a khuntti or kudali/ kudal.

Pruning

Pruning is the removal of any excess or undesirable branches, shoots, roots or any parts of a plant to allow the remaining parts to grow normally or according to the desire of the pruner. Most of the fruits needs regular pruning. Pruning of trees is mostly done with a pruning saw or secateur by climbing on trees or ladder.

Spraying/Plant Protection

Spraying the fruit and vegetable

Table 3 Area and production of major horticultural crops in Himachal pradesh

Crop	Area, 000 ha	Production, 000 MT	Av. yield, q/ha
Fruits			
Apple	85.6	393.65	45.9
Citrus fruit	38.7	13.11	3.3
Mango	29.8	16.9	5.6
Walnut and dry fruit	16.06	3.07	1.8
Other temperate fruits*	31.9	17.79	5.57
Other sub-tropical fruits**	5.07	2.97	5.85
Vegetables			
Potato	12.8	140.1	109.45
Peas	7.9	81.01	102.54
Other vegetable	21.2	418.89	197.58

*plum, peach, apricot, pear, cherry etc.
**litchi, guava, papaya, grape, jack fruit

Table 4 Planting practices for different fruit crops

Crop	Pit size, width and depth, cm	Planting spacing, m	Crop	Pit size, width and depth cm	Planting spacing, m
Apple	100 x 100 x 100	3.0-7.5	Walnut	100 x 100 x 100	10 x 10
Citrus	100 x 100 x 100	4.5-6.0	Plum, apricot, almond and cherry	100 x 100 x 100	6 x 6
Mango	100 x 100 x 100	8-10			
Litchi	100 x 100 x 100	8-10	Peach	100 x 100 x 100	4.5
Pecan nut	100 x 100 x 100	10 x 10	Kiwi	100 x 100 x 100	6 x 4

plants against timely control of insect-pests and diseases is an important horticultural practices. Spraying of different fruits and vegetable crops is done by hand sprayer, knapsack sprayer and power sprayer.

Irrigation

Irrigation is very important in fruit and vegetable crops as sufficient moisture must be maintained in the soil for obtaining the optimum yield of good quality fruits and vegetables. The irrigation of tree and vegetable crops is done by flooding of basins. Pressurized irrigation systems are not very popular in the state.

Harvesting/Digging

The farmers have their own traditional ways of harvesting. Harvesting of all the fruits is done manually by hand picking or by climbing on the tree directly or sometimes directly beating the branches with a long bamboo.

The apple is harvested by hand picking with some twisting action. For harvesting of Mango, some people use the conventional harvester with a hook or frame and net at the end of a long bamboo pole (**Fig. 3**). Techniques for harvesting of mango and citrus are available elsewhere in the country. However, no such techniques have been standardized for harvesting of fruits in the state. Harvesting of pecan-nut is done manually by beating the fruits with a bamboo. Litchis are harvested by their stalks (bunches) manually.

Fig. 3 Conventional mango harvester and pecan nut harvesting with a bamboo

Likewise, digging of potato, onion, ginger, garlic and turmeric are done manually by kudali or khurpa. The dug out materials are picked manually from fields. Harvesting/plucking of different vegetables such as peas, tomato, chilies, French bean, and brinjal. are done manually.

Future Need of Mechanization

Most of the operations for raising horticultural crops are performed manually with traditional tools having very low efficiency and more drudgery that need to be mechanized so that farmers of the state may benefit and pay meaningful attention on these crops. The following are the timely and labour intensive operations that can be mechanized.

Field Preparation

Field preparation for horticultural crops manually with a spade and with bullocks is very labour intensive and drudgery oriented. This system can be mechanized by introduction of a light-weight power source such as the power tiller (**Fig. 4**). Different firms are manufacturing the power tiller in India. The power tiller can be used for seed-bed preparation resulting in timeliness of operation with high efficiency as compared to the manual and bullock system.

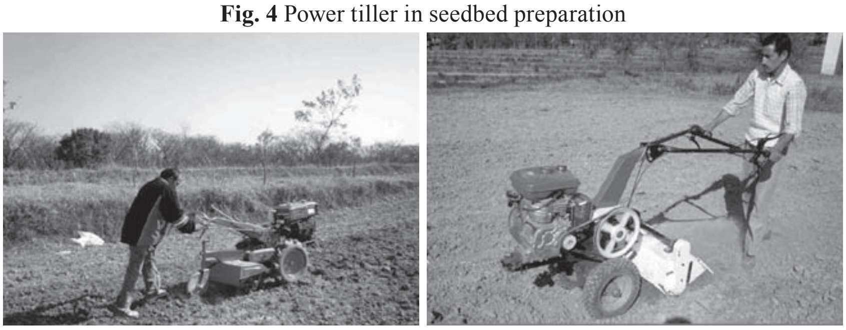
Propagation of Plants

The success of budding and grafting of mango and apple is higher under high humidity. A healthy nursery for vegetable crops promotes faster growth under controlled temperature and relative humidity. Hence, for propagation of healthy plants, the greenhouses with temperature

Table 5 Planting practices for vegetables and spice crops

Crop	Planting material	Ridge spacing, cm	Seed spacing, cm
Potato	Tuber	50-60	15-20
Peas	Seed	30-60	7.5
Garlic	Clove	20	10
Ginger	Rhizome	30	20
Turmeric	Rhizome	30	20
French bean	Seed	60	15
Corriander	Seed	23	15
Bhindi	Seed	45	20
Spinach	Seed	20	7.5

Fig. 4 Power tiller in seedbed preparation



control and misting facilities are essential for designing/adoption of different crops and location. Low cost conventional bamboo polyhouse can also be used for this purpose. The trays for raising seedlings with soil/media block need development. A transport system for nursery plants from nursery to the field of transplanting also needs development.

Digging of Pits for Planting

This operation needs to be mechanized with some mechanical diggers such as the tractor/power tiller with an attached post-hole digger that is commercially available. The auger digger as an attachment to the power tiller, developed by Kathirvel et al. (1990), is capable of digging holes of 22.5 cm diameter up to a depth of 45 cm with a capacity of 35-40 holes/h. A self-propelled post-hole digger can be used for pit digging.

Sowing/Dibbling

The vegetable planter developed by TNAU, Coimbatore, along with the garlic planter developed by Garg et al. (2003) and the power tiller operated potato planter developed by Gupta et al. (1994) should be popularized for a large saving over planting by traditional methods. A transplanter for seedlings with a soil block for cabbage, capsicum, brinjal, cauliflower and tomato needs development. A transport system for the seedling trays also needs to be designed.

Basin Preparation

Power tillers as commercially available in the market can be used for basin preparation in apple, mango and some other horticultural crops successfully. Even lightweight power weeders commercially available in the market having weighing 100-115 kg can be used for this operation. On an average, 15 basins/h can be prepared with a power tiller as compared to two basins/h with a spade in mango orchard (Anonymous, 2004).

Weeding

Weeding in vegetable crops is a major labour intensive and costly operation. Weeders for tomato, onion, garlic and other vegetables crops need developments. The power tiller rotavator can be successfully used for controlling weeds in different fruit orchards.

Table 6 Planting practices for vegetables crops (transplanting)

Crop	Ridge spacing, cm	Seedling spacing, cm
Tomato	60-90	30-45
Cabbage	30-60	30-45
Cauliflower	45-60	30-45
Onion	15-20	7.5-10
Chilli	45	45
Brinjal	60	45
Capsicum	60	45

Fig. 5 Mango harvester and fruit harvester

Spraying

Plunger type tractor/power tiller operated sprayers that have been designed by the Indian Institute of Horticultural Research, Bangalore and TNAU, Coimbatore can be introduced. The power tiller operated boom sprayer developed by Mathew et al. (1992) for spraying the crops planted in rows with a swath width of 3.5 m and a speed of 2.25 km/h can be popularized. An aeroblast sprayer needs to be evaluated for tall fruit trees. Long boom and high clearance sprayers need to be introduced.

Pruning

Deciduous fruits trees like apple, pear, peach, plum, almond, apricot, grapes and kiwis need annual pruning in order to keep them in proper vigour and for obtaining high yields of superior quality over the years. Mango trees can give off-season fruits by pruning. Hence, the long arm pruner or pole pruner that is mechanical/tractor operated can be introduced.

Irrigation

Sprinkler and drip irrigation systems can be introduced in nursery raising, vegetables crops or in different fruit orchards.

Harvesting/Digging

The harvesting of fruits involves plucking of individual fruits and mass handling/transport. Utmost care needs to be taken while harvesting and handling of fruits. The harvesting of apples and plums is a very skilled operation because there is a chance of fruit damage. The manual operated mango harvesting device designed and developed by Sapowadia, et al. (2001) working on the principle of impact cum shear type can be introduced in the state (**Fig. 5**). Apple, litchi, pecannut and plum harvesters need to be designed. A fruit harvester working on the principle of impact that is available in the market can be used for pears and guava fruits (**Fig. 5**). Suitable harvesting and transport systems for different type of fruits are required for convenient, savings in labour and time and to reduce post harvest losses.

Bullock/power tiller operated potato diggers have been designed and their feasibility can be seen in the hills. A digger for other root crops like ginger, turmeric, carrot and radish is needed. A bhindi plucker that is available in the market can be used. A pea plucker needs to be developed. Harvesting and handling of crops like cauliflower, cabbage, beans, brinjal and tomato involves lot of labour. A suitable harvest and transport system needs to be developed.

Conclusions

The level of mechanization of horticultural crops in hills could be increased by adopting the improved tools/equipments for different operations. Much more R & D on the mechanization of horticultural crops is the need of hour so that hill farmers may be benefited.

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(Continued from page83)

Performance Evaluation of a Yam (Dioscorea spp.) Harvester

damage of 18 % and a high number of tubers successfully harvested of 93 %. Further improvement of the implement will be to reduce the amount of tuber damage.

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Development of Solar Cabinet Dryer for Dates

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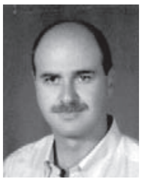

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Abstract

The prototype and small scale production model of a natural convection solar cabinet dryer was designed, constructed and tested for the drying of dates. The prototype had a single drying floor of 1.6 m^2. The production model had two trays with holding area of 6 m^2 and functions as mixed mode type. The perspective, principal and section views of the dryer showing the form designs were presented. The cost of construction materials for the prototype was US$374 and for the production unit was US$516.

The dryer units were tested over three production seasons. Test results showed that both units reduced moisture to about half the initial moisture content in 23 to 33 hours (3-4 days of sunshine). The moisture reduction was from 40 and 50 % to 20 and 30 % moisture content wet basis under ambient conditions of 27 to 43 ºC temperature, 31 to 77 % relative humidity, 3 to 5 m/s wind speed and 19 to 23 MJ/m^2/day total solar radiation. The production dryer gave an overall thermal efficiency of about 55 %.

Introduction

Various solar drying systems have been developed for drying food and agricultural products but most of them are for products other than dates. Many of the existing solar dryers are for grain, vegetables, some fruits and fish (Al Amri, 1997; Al Yahya and Ismail, 1998; Basunia and Abe, 2001; Fuller et al., 1994; Moy, 1993; Sodha et al., 1987, Zaheb; and Elsayed, 1994).

Dates have been recognized for a long time as an energy-rich food throughout many countries of the world. They are produced as a major crop for both local consumption and export in the Gulf Region. In Oman annual production is estimated at about 200,000 tonnes (College of Agriculture, 1997). Dates are sun-dried by farmers in the open air resulting in long drying periods (14 to 21 days) and poor product quality (Ampratwum, 1998a). Solar energy is abundant in the Gulf region. It ranges from 14.00 MJ/m^2/day in December to 22-23 MJ/m^2/day in April, May and June (Dorvlo and Ampratwum, 1998). The use of solar energy in drying under controlled conditions will improve quality and reduce the cost of drying (Sodha et al., 1987). However, limited work has been done on using well designed solar dryers for dates (Ahmad and Khan, 1997). A survey of the methods of drying dates in Oman has revealed that well designed solar dryers are needed by date farmers (Ampratwum, 1998a). This conclusion applies generally to the Gulf region.

The development of solar powered technology for drying dates with the aim of reducing the time span required for drying and improving the quality of dried product was initiated to produce efficient date dryers (Ampratwum, 1998b). A prototype solar cabinet dryer that was built for drying of dates based on an air heating system, was evaluated in preliminary trials in 1998 (Ampratwum and Dorvlo, 1998). The dryer needed to be developed further for use by date farmers. This paper reports on the testing of the prototype under loading conditions and on the design, construction and testing of a small scale production model. The long term goal of the research work was to improve the open air sun drying system currently used by most date farmers, through the application of a well developed solar technology. Specific objectives were the design of a natural convection solar dryer, construction of the dryer and testing of the dryer for the drying of dates.

Procedure

Prototype and Production Model Design

A prototype natural convection solar cabinet dryer which has been designed to have a collector area of 1.6 m^2 (25-50 kg capacity) was used. The prototype was a scaled down version of a large scale solar dryer with 16 m^2 solar collector area designed to dry a daily batch of 100 kg of dates from 49 % moisture content wet basis (m.c.w.b) to 21 % m.c.w.b in drying time of 9.8 hours under average ambient conditions of 32 ºC air temperature and 65 % relative humidity with incident

Fig. 1 Photograph of prototype solar cabinet dryer

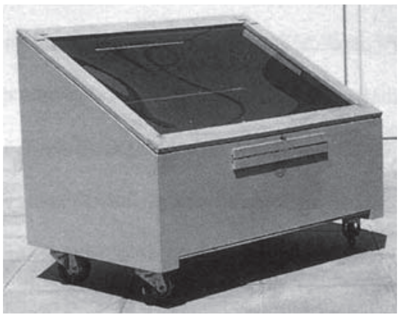
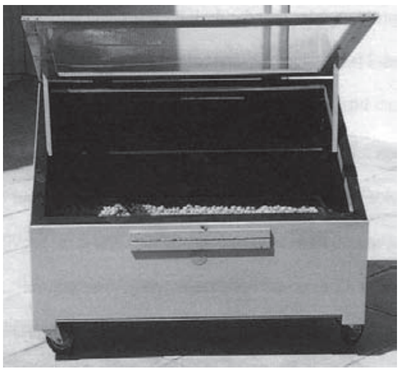


Fig. 2 Photograph of prototype solar cabinet dryer (open)



solar radiation of 22.5 $MJ/m^2/day$ (Ampratwum, 1998b). Following the design procedures used in the large production unit and prototype, a small scale production model was designed to hold drying material of 50 to 100 kg on two (upper and lower) trays. The small scale production dryer designed received solar radiation on a horizontal surface of 3.0 m^2 in the upper tray. The lower tray, which also provided 3.0 m^2 drying surface area received indirect solar energy from heated air which passed over it. The dryer was therefore of mixed mode type.

Both the prototype and small scale production dryers have the shape of a home cabinet with plexiglass cover. The prototype model had a single pitch top while the production unit had a top in the form of a double-pitch (gable) roof. They were provided with inlet and outlet ports for airflow and were set on casters for mobility. The photograph, perspective and principal views are shown in **Figs. 1** to **4** for the prototype and in **Figs. 5** to **8** for the small scale production model.

Construction of the Dryers

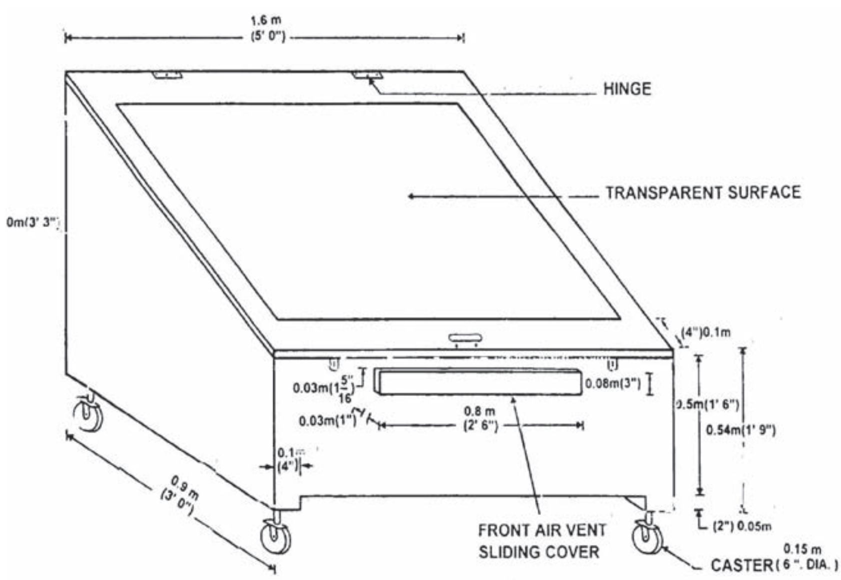
The prototype was constructed in the early 1990's when preliminary research activities started. The small scale production unit was constructed in the summer of 2000. Drawings were prepared to guide the construction of the dryers.

The dryers were built from locally available and durable construction materials including lumber and plywood. The cost of construction materials for the prototype was \$374 and for the small scale production model was \$516. Cost of labor used in construction was equivalent to the cost of materials.

Testing of Dryers

The prototype which had earlier been evaluated at no load (Ampratwum and Dorvlo, 1998) and the small scale production unit were tested for the drying of dates. Two date varieties, namely Bonaringa and Khalas, were dried with the small scale production model. Only Khalas was used in the prototype. Tests were conducted over three production seasons, namely 2000, 2001 and 2002, under ambient conditions of 27 to 43 ºC temperature, 31 to 77 % relative humidity, 3 to 5 m/s wind speed and 19 $MJ/m^2/day$ average total solar radiation. The prototype was tested in 2001 and 2002 and the production model was

Fig. 3 Perspective view of prototype



tested in 2000 and 2002.

During the tests, samples of dates in small containers were placed randomly in the dryers, with four replicates in the prototype and five replicates in the small scale production unit. The containers were exposed to sunshine from morning to sunset. The dates were exposed for three days in the prototype model and four days in production model. From recorded masses the hourly percent moisture contents and the daily rate of moisture loss were computed.

The computations were made as follows:

$$X_{i+1} = \left[\frac{M_i X_i / 100 - (M_i - M_{i+1})}{M_{i+1}} \right] 100\ \%, \quad ......(1)$$

where M_i is the wet mass and X_i is the percent water content wet basis at the i[th] reading.

Daily rate of moisture loss, g/h =

$$\frac{(M_m - M_s)}{\theta_s}, \ ....(2)$$

where M_m is the mass (g) in the morning, M_s is the mass (g) at sunset, and θ_s is the hours of sunshine.

The initial and final moisture contents of the dates during each test were determined by the oven air method (Henderson et al., 1997). The method consisted of drying 5 to 10 grams chopped dates for 72 to 96 hours at 103 ºC. The rate of water evaporated during drying in the small scale production dryer was calculated from the expression (Sodha et al., 1987):

Rate of mass of water evaporated,

$$M_{H2O}\ kg/h = \frac{M_i (MC_{wbi} - MC_{wbf})}{\theta_d (100 - MC_{wbf})}, \ ...(3)$$

where M_i is the initial mass of product in kilograms; MC_{wbi} is the initial product m.c.w.b, %; MC_{wbf} is the final product m.c.w.b, %, and θ_d is the drying time in hours.

The temperatures and relative humidities in and out of the dryer were monitored with thermometers and relative humidity meters placed outside, while data loggers were placed inside the dryer to monitor

Fig. 4 The principal views

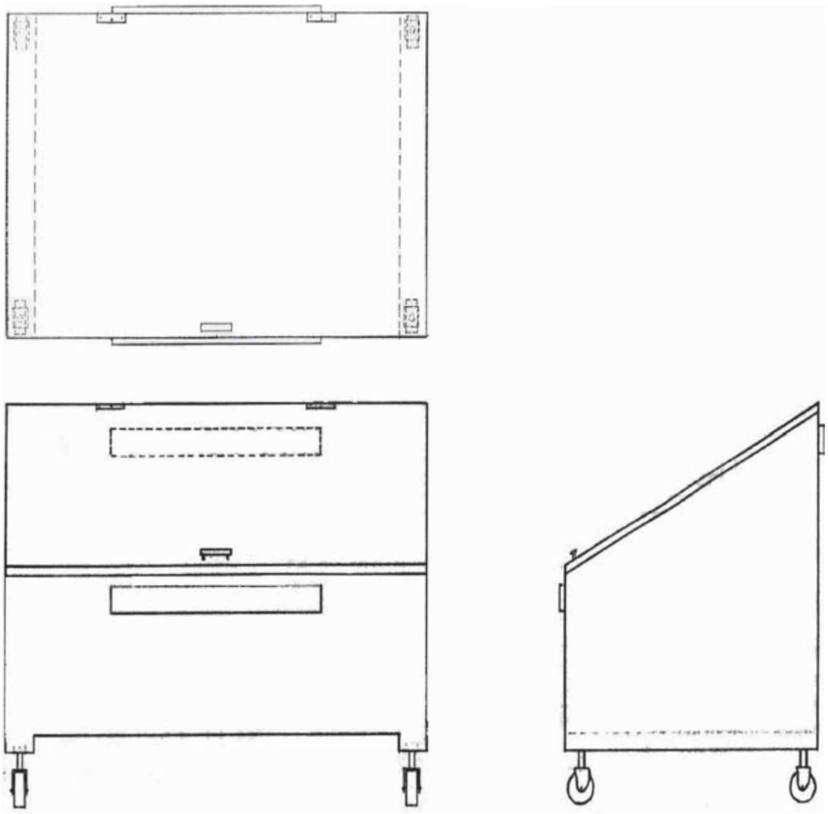


Fig. 5 Photograph of small scale production dryer

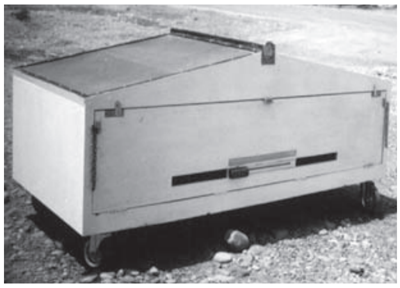
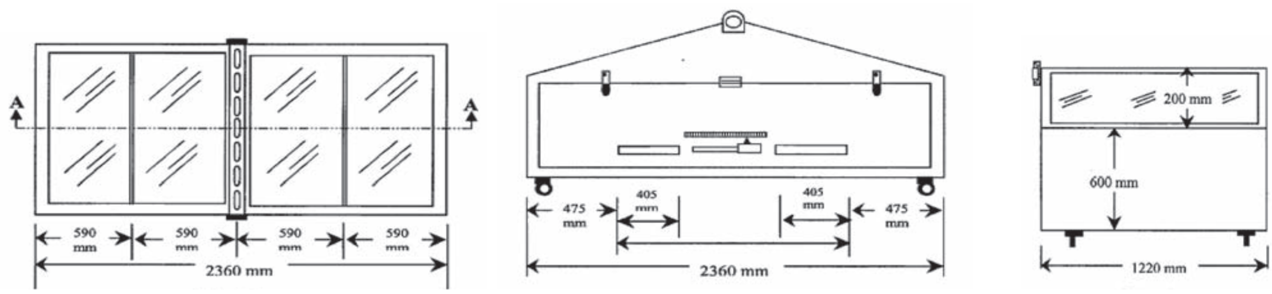


Fig. 6 Photograph of small scale production dryer (open)

Fig. 7 Principal views of production model



the environmental conditions inside the dryer.

The thermal efficiency of the small scale production dryer was calculated from the following relationship (Sodha et al., 1987).

Overall thermal efficiency, η_{th} =

$$\frac{\text{Energy of water evaporation}}{\text{Net energy input}} 100\% = \frac{M_{H2O} \text{ x } Lv}{IA\eta_e} \text{ ....(4)}$$

where M_{H2O} is the rate of mass of water evaporated kg/h; Lv is the latent heat of evaporation of water, 2260 kJ/kg; I is the incident radiation, MJ/m^2/day (24h); A is the collector (top tray) area, m^2 ; and η_e is the collector efficiency % (30 %).

The initial batch mass dried on the top tray of the small scale production dryer averaged 21.44 kg.

Result and Discussion

The results of calculations of moisture contents of dates in the prototype dryer are presented in **Table 1**. The average initial m.c.w.b. was 47 %. Over a three-day period the moisture content dropped to 26 % m.c.w.b in 23 hours of sunshine. The trend of percent moisture loss is shown in **Fig. 9**.

Results of calculations of moisture contents and rate of moisture loss for dates in the small scale production dryer upper tray are given in **Table 2**. The production model dried dates at 43 % m.c.w.b average to 22 % m.c.w.b in 33 hours (4 days) of sunshine in the upper tray and to 27 % m.c.w.b in the lower tray in the same period.

The moisture content obtained in the upper tray was close to the design value of 21 % m.c.w.b. but it took a longer time to achieve this moisture target level than that considered while designing the dryer. A plot of the rate of moisture loss versus time (day), **Fig. 10**, shows typical drying characteristics of wet solids in air. Most of the drying took place in the first two to three days. The thermal efficiency of the production unit was 55 %. This efficiency of the dryer fell within the range of 33 to 64 % reported for solar dryers by other researchers (Sodha et al., 1987). The results indicate that the dryer can dry dates to half their initial moisture content in 3 to 4 days. In direct open air sun-drying this is achieved by farmers in 14 to 21 days (Ampratwum, 1998a).

The dried dates were of good quality as evidenced by their taste. The moisture contents of the dates dried with the production model reached an acceptable level of consumer appeal based on reaching about 20 % m.c.w.b. The small scale production dryer has two trays. The top tray which received solar heat both from direct radiation and from ambient air gave dates with lower moisture content. The dryer, with a capacity of up to 100 kg, meets the drying requirements of the Omani date farmers.

Conclusion

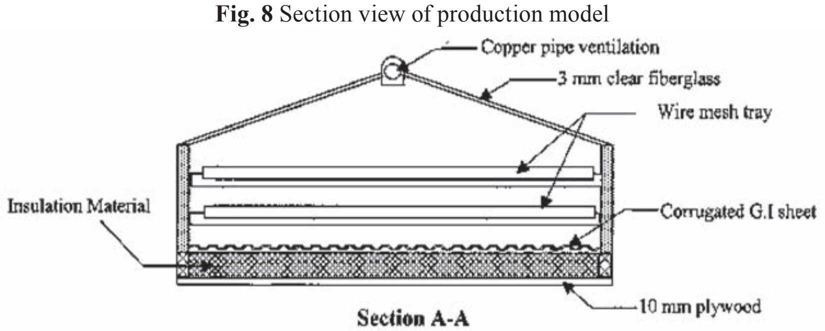
Dates are commonly dried unprotected in the sun resulting in long drying time and low quality products in Oman.

A solar powered dryer was developed to improve open air sun-dry-

Table 1 Moisture contents of dates in prototype dryer

Day	Time	Sunshine hours (Ave. of 9 hrs per day)			% moisture content wet basis		
					YR 2001	YR 2001	YR 2002
		Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
1	7:00 am						39.9
	10:00 am					51.2	
	11:00 am						37.9
	12:00 noon				49.6	49.2	
	1:00 pm						34.2
	2:00 pm				44.7	42.9	
	4:00 pm				42.2	41.1	
	6:00 pm	6	8	9		39.9	
2	7:00 am						29.2
	9:00 am				39.3	39.3	
	11:00 am				38.0	37.1	27.9
	1:00 pm				34.8	33.7	26.9
	3:00 pm				32.1	31.3	
	5:00 pm	9	9	9	31.2	30.3	
3	7:00 am						24.3
	9:00 am				28.2	29.8	
	11:00 am				29.3	28.7	23.9
	1:00 pm				27.6		22.9
	From 6 am	7	5	7			
Total		22	22	25			

Fig. 8 Section view of production model



ing currently used by date farmers.

A prototype and a small scale production model dryer was designed, constructed and tested with drying areas 1.6 m^2 and 6.0 m^2, respectively.

The solar dryers can reduce moisture contents to about one-half the initial moisture content in up to 33 hours (3 to 4 days of sunshine) compared to 14 to 21 days in open air sun-drying.

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Table 2 Dates moisture contents and rate of moisture loss in production dryer

Item	YR 2000 Test 1	YR 2000 Test 2	YR 2002 Test 3	Average
Initial % MCWB	32.99	55.60	39.90	42.83
Final % MCWB	15.94	27.48	22.96	22.13
Initial batch mass, kg	15.43	21.20	27.96	21.44
	Rate of moisture loss, g/h			
Day 1 (Sunshine hrs)	4.32 (8)	6.47 (5)	7.72 (10)	6.17 (8)
Day 2 (Sunshine hrs)	2.75 (7)	4.71 (7)	3.16 (10)	3.54 (8)
Day 3 (Sunshine hrs)	1.10 (8)	3.00 (10)	0.69 (10)	1.60 (9)
Day 4 (Sunshine hrs)	0.50 (8)	2.00 (10)	1.09 (6)	1.20 (8)
Total sunshine hrs	31	32	36	33

Fig. 9 Moisture loss in prototype dryer

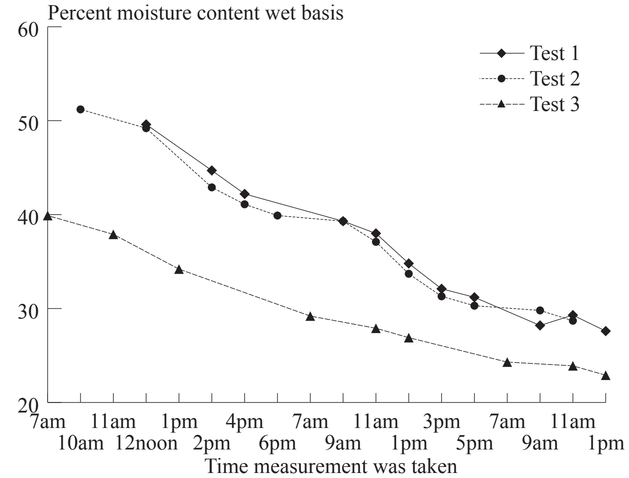
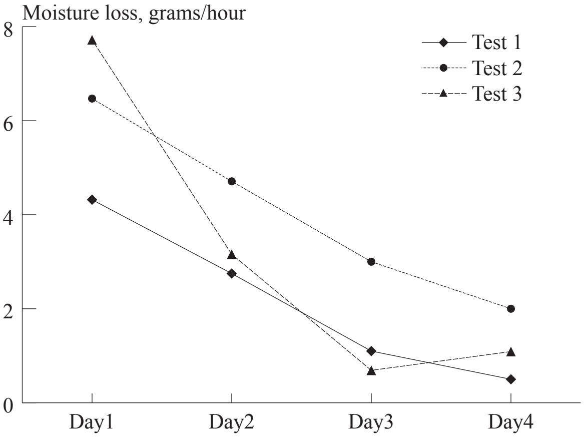


Fig. 10 Rate of moisture loss in production dryer



Mechanical Consideration for Design and Development of Furrow Openers for Seed Cum Fertilizer Drill

by

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Abstract

The identified furrow openers such as shoe, shovel and inverted - T types were designed and fabricated in the research workshop at CIAE, Bhopal, India. Prime considerations were given to minimum soil disturbances and reduced tendency for clogging. The components of the furrow opener were fabricated by following the standard techniques. The material used for fabrication of furrow openers conformed to the standards and grades of IS 6813: 2000. The testing was conducted in the laboratory in 2003. The potential of the furrow openers were compared on the basis of draft requirement, soil disturbances and seed emergence. The inverted - T type furrow opener required the lowest draft of 32.12 kgf, minimum soil disturbances (4-5 cm) and minimum clogging frequency as compared to the shovel and shoe type furrow opener. Seed emergence percentage (86.66 %) per meter of row length was found highest for the inverted - T opener as compared to the shoe (70.90 %) and shovel (62 %) type furrow opener.

Introduction

The population of tractor and animal drawn seed drills are increasing day by day in India. In the year 1972, the population of bullock drawn seed drill was 4,049,000, which increased to 8,000,000 in the year 1995. Seeding and fertilizer placement are two operations, which, if done in the desired manner, could increase production substantially. The furrow opener of a sowing device is the final modifier of soil environment in a seedbed. Hence, it is one of the most important components of a seed cum fertilizer drill. The furrow openers have problems of clogging in Kharif due to high moisture and they do not penetrate deeper in Rabi sowing due to low moisture and high bulk density.

Srivastava (1985) evaluated different types of furrow openers of bullock-operated seed cum fertilizer drill in the black soils. The study was conducted on the basis of penetration ability of furrow openers, non-clogging of seed and fertilizer in boots, on the amount of soil disturbance and draft. It was reported that the shoe type furrow opener gives the best performance. Darmora et al. (1995) found that draft requirements of furrow openers was increased with opener width and boot wedge angle, whereas lateral and vertical separation between seed and fertilizer was influenced by transverse tube spacing and boot geometry. A hoe type opener having 300 wedge angle, 40 mm transverse tube spacing and a baffle plate at its boot performed better than other furrow openers. Collins and Fowler (1996) reported that draft forces increased significantly from 1,700 to 4,300 N/m for all furrow openers when seeding depth was increased from 1 to 5 cm. Further, they stated that the average increase in draft for all furrow openers was 4 % for each km/h increase in speed between 1 to 5 cm seeding depth. Dransfield et al. (1964) reported that rake angle of a furrow opener was proportional to the force on it. They found that both the horizontal and vertical forces increased with increase in rake angles. Siemens et al. (1965) concluded analytically, as well as from experimental results, that a rake angle of furrow opener of 25^{o} gave minimum draft.

Soil poses two different types of problems in Kharif and Rabi seasons in Chhattisgarh. During Kharif season, when the soil moisture is above 25 % the soil becomes plastic and very sticky and does not flow properly. In such conditions, the problems of clogging and sticking of soil around the furrow opener is common. In Rabi conditions when the soil moisture recedes rapidly the seedbed is generally cloddy and trashy. The soil becomes very hard and it poses problems in fine seed-bed preparation and penetration of furrow openers. Keeping all above points in view, the work on development of furrow openers for bullock drawn seed cum fertilizer drill has been undertaken to identify a suitable type of furrow opener and improve its design with a view to make it suitable for both, Kharif and Rabi sowing.

Table 1 Specific soil resistances at a depth 15 cm

Soil type	Specific resistance, kg/cm^2
Light	0.12
Midium	0.15
Heavy	0.20
Very heavy	0.25

Source: Dubey, 2003

Design of Furrow Opener

Design of Shank for Shovel Opener

The furrow-opening tool was attached at one extreme end of the shank and bent suitably so as to have a contact angle, α, called rake angle or load angle. The other end of the shank was fixed to the frame as shown in **Fig. 1**. Referring the figure, nomenclatures are defined as:

b x h = Shank cross-section, mm^2,

l= Length of breast of the shovel, mm,

R = Radius of curvature of bent portion of shovel (The slope of the shovel is most frequently adopted in the range from 100 to 250 mm and the radius of curvature R ≤ 120 mm),

h_0 = Height of the shank from its tip to the bent portion, mm,

d = Maximum operating depth, mm.

H_1 = Shank height from the frame to the top end of the breast, mm,

H = Height of shank from the tip of shovel to the frame, mm,

α = Rake angle, deg,

ΔH = Length of the upper part of tine serving for fastening, cm and

k_0 = Soil resistance, kg/cm^2.

From the geometry, the radius of curvature 'R' of the bent portion of the shovel is given by

$$R = \frac{h_0 - l \sin \alpha}{\cos \alpha} \quad \text{.................................(1)}$$

Substituting the values, h_0 = 140 mm, l = 110 mm, and α = 25º in Equation 1. The value of h_0, l and α have been taken on the basis of research findings by Dubey (1985).

R = 103.17 mm ($\because$ $R \leq 120$ mm)

During the operation, an effective draft force 'D' acts at the tip of the tool that generate a bending stress (σ) at the bent causing bending of the shank. For calculation purpose soil resistance, k_0 is assumed to be 3-5 times higher (as matter of safety) than the specific resistance. The soil resistance for different soils is given in **Table 1**.

Force exerted to the opener is

$$D = k_0 \times w \times d \quad \text{.................................(2)}$$

Where

D = Draft force, kgf,

k_0 = Specific soil resistance, kg/cm^2 = 0.25 kg/cm^2 is selected (**Table 1**) for heavy soils, for calculation k_0 was assumed to be 3-5 times higher than the specific resistance,

w = Width of opener, cm and

d = Depth of opener, cm.

Assuming w = 2.5 cm, d = 10 cm

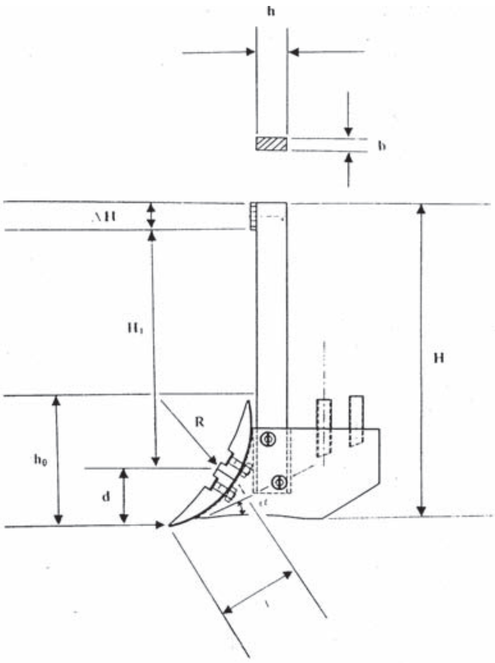


Fig. 1 Geometry of shovel type furrow opener

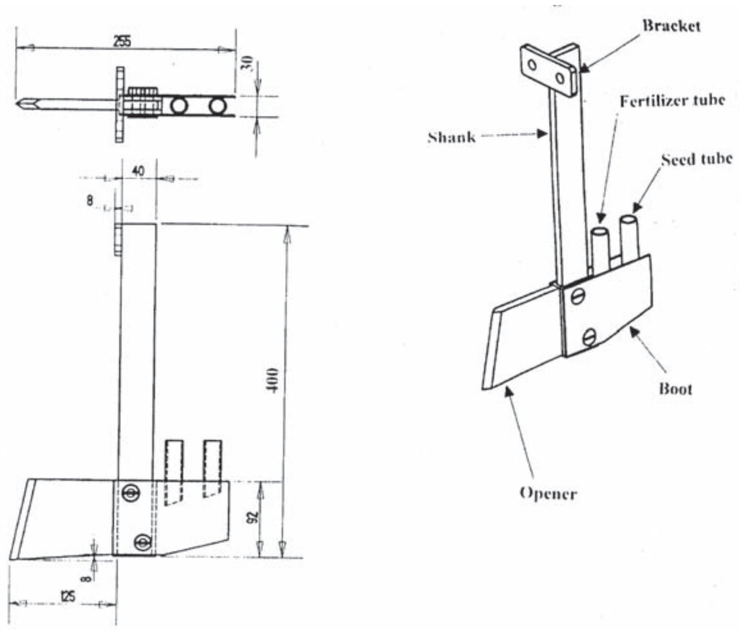


Fig. 2 Development of inverted - T type furrow opener

and k0 = 0.75 kg/cm^2 and substituting the values in Equation 2.
D = 18.75 kgf.

Now taking a factor of safety of three for MS shank the total draft exerted on the opener will be 56.25 kgf. The tine can be taken as a cantilever, so the maximum bending moment for a cantilever length of 40 cm length (Kurtz et al. 1984) is
Bending moment (M) = Draft (kgf) x Length of shank (cm). ....(3)
M = 56.25 x 40 = 2250 kgf-cm.

The section modulus of the shank was computed from the classical flexure formula (Seely et al., 1952 and Timoshenko et al., 1964) as given in Equation 4.

$$\delta = \frac{MC}{I} \quad ....(4)$$

Where
δ = Bending stress, kgf/cm^2,
M = Bending moment, kgf cm,
C = Distance from the natural axis to the point at which stress is determined, cm and
I = Moment of inertia of the rectangular section, cm^4.

The section modulus axis was computed by using the formula,

$$z = \frac{I}{C} \quad ....(5)$$

From Equation 4 and 5,

$$z = \frac{M}{\delta} \quad ....(6)$$

Assuming a bending stress equal to 1000 kgf/cm^2, (Sengar, 2002)

$$z = \frac{M}{\delta} = \frac{2250}{1000}$$

z = 2.25 cm^3,
and the section modulus of the furrow opener is

$$z = \frac{bh^2}{6} \quad ....(7)$$

The most assumed ratio of thickness to width of tine, b:h = 1:3 to 1:4.

Assuming, b:h = 1:4, i.e. h = 4b.
From Equation 7,

$$z = \frac{b \text{ x } (4b)^2}{6}$$

$$2.25 = \frac{b^3 \text{ x } 16}{6}$$

b^3 = 0.84 cm^3 and
b = 0.943 cm (10 mm).

Considering the factor of safety and availability of material of standard size, the thickness of shank selected was 10 mm. Therefore, the width of the shank, h = 4b.

h = 4 x 10 = 40 mm. Therefore, the cross-section of the shank will be b x

Fig. 3 Components of shoe, shovel and inverted type furrow opener

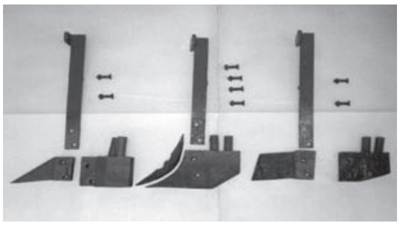


Table 2 Specifications of the furrow opener

Particulars	Shoe	Shovel	Inverted - T
Rake angle, deg.	28	30	28
Wedge angle, deg.	45	60	45
Boot height, mm	100	150	100
Boot length, mm	80	120	80
Boot width, mm	45	32	30
Length of opener, mm	120	100	120
Width of opener, mm	12	25	12
Dia. of seed tube, mm	25	25	25
Dia. of fertilizer tube, mm	25	25	25
Angle of seed tube, deg.	15	0	0
Angle of fertilizer tube, deg.	5	5	5
Spacing of seed and fertilizer tube, mm	0	25	25
Spacing of seed and fertilizer tube across width, mm	20	0	0
Weight of furrow opener, kg	3.5	3.8	3.35
Length of shank, mm	400	400	400
Width of shank, mm	40	40	40
Thickness of shank, mm	10	10	10

Fig. 4 Relationship between speed and draft (Kharif)

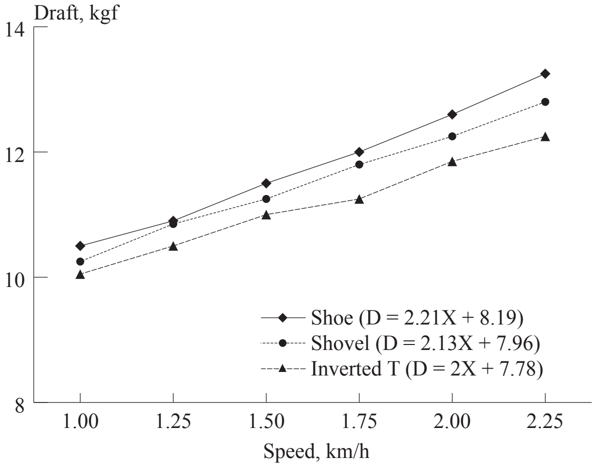
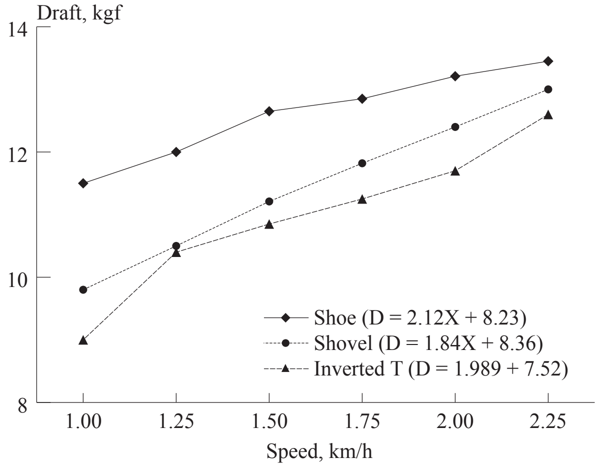


Fig. 5 Relationship between speed and draft (Rabi)



h = 10 x 40 mm^2.

This section would yield a maximum deflection of

$$Y_{max} = \frac{Dl^3}{3EI} \quad \text{......................................(8)}$$

Where

Y_{max} = Deflection produced due to loading, mm,

D = Draft force, kgf,

l = Length of the shank, mm,

E = Modulus of elasticity = 2 x 10^4 kg/mm^2 (for Mild steel) and

I = Moment of inertia, mm^4.

Moment of inertia was calculated by the following formula

$$I = \frac{bh^2}{12} \quad \text{..(9)}$$

= 53333.33 mm^4

Therefore,

$$Y_{max} = \frac{56.25 \times (400)^3}{3 \times 2 \times 10^4 \times 53333.33}$$

Y_{max} = 1.12 mm.

Construction Details

The components of furrow openers were fabricated by following the standard techniques. The material should, as for as possible, confirm to standards and grades of IS 6813: 2000. **Fig. 2** shows the designed inverted -T type furrow opener.

The detailed specifications of the shovel type, shoe type, inverted T type furrow openers are given in **Table 2**.

Experimental Procedure for Laboratory Tests

The tests were conducted in a laboratory soil bin under following soils conditions

a. Soil conditions encountered during Kharif sowing; Soils have 14.50 % mc (wb) of soil profile and 15.65 % mc (wb) at 10 cm depth. Compaction varyies uniformly from top to bottom layer of 15 cm depth with cone index varying uniformly from 0 to 4.06 kg/cm^2.

b. Soil conditions encountered during Rabi sowing on residual moisture; Soils have 12.90 % mc (wb) of soil profile and 16.12 % mc (wb) at 10 cm depth and. Compaction varies uniformly from top to bottom layer of 15 cm depth with cone index varying uniformly from 0 to 4.35 kg/cm^2.

The experiments were conducted in a laboratory soil bin under simulated test bed and moisture content conditions. The following variables were recorded during the tests

a. Independent Variables

Forward speed

Depth

Type of furrow openers

b. Dependent Variables

Draft,

Soil disturbance

Seed emergence

Table 3 Laboratory tests of different furrow openers for Kharif and Rabi soil

Soil bin condition	Av. speed, km/h	Av. draft, kgf			Soil disturbance from furrow center, cm		
		Types of furrow opener					
		Shoe	Shovel	Inverted - T	Shoe	Shovel	Inverted - T
Kharif	1.00	10.50	10.25	10.05	+3.1 to -3.8	+3.0 to -2.4	+2.0 to -2.2
	1.25	10.90	10.85	10.50	+3.0 to -3.2	+3.5 to -2.6	+2.1 to -2.4
	1.50	11.50	11.25	11.00	+3.2 to -3.8	+3.8 to -2.1	+2.6 to -3.0
	1.75	12.00	11.80	11.25	+3.0 to -3.2	+3.0 to -2.8	+2.5 to -2.9
	2.00	12.60	12.25	11.85	+3.2 to -3.8	+3.6 to -2.2	+2.2 to -2.9
	2.25	13.25	12.80	12.25	+3.0 to -3.5	+3.6 to -2.5	+2.8 to -3.0
Rabi	1.00	11.50	9.80	9.00	+4.0 to -5.1	+3.0 to -3.3	+2.4 to -3.0
	1.25	12.00	10.50	10.40	+4.0 to -4.4	+3.8 to -3.2	+2.6 to -2.3
	1.50	12.65	11.21	10.85	+4.8 to -4.2	+3.5 to -3.6	+2.6 to -3.0
	1.75	12.85	11.82	11.25	+2.2 to -4.1	+3.0 to -3.8	+2.5 to -2.9
	2.00	13.21	12.40	11.70	+3.7 to -4.3	+3.6 to -3.2	+2.2 to -3.0
	2.25	13.45	13.00	12.60	+3.2 to -4.8	+3.2 to -3.5	+2.8 to -2.5

Fig. 6 Relationship between depth of furrow opener and draft (Kharif)

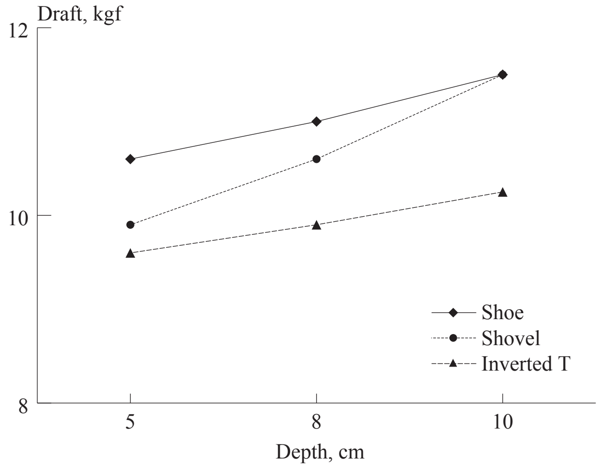
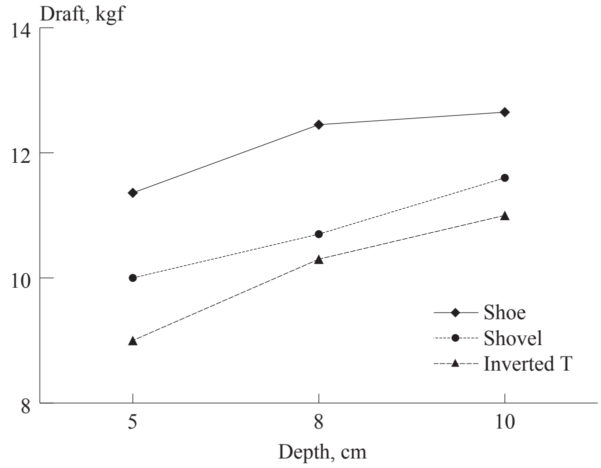


Fig. 7 Relationship between depth of furrow opener and draft (Rabi)



Results and Discussion

Effect of Speed of Operation on Draft Force

The performance data of all three furrow openers tested at the soil bin at different operational speeds are presented in the **Table 3**, it was observed that the draft forces were lowest in the case of inverted - T type furrow openers in both Kharif and Rabi soil condition. This could be attributed to its lower boot width and better design of soil working parts. A linear relationship was observed for increase in speed with respect to increase in draft at sowing depth of 10 cm (**Figs. 4** and **5**). In Kharif season 17-25 % increase in draft was observed for the increase in speed from 1 km/h to 2.25 km/h. However percentages increase in draft force was more in case of Rabi season it was in the range of 30-40% for 10 cm sowing depth and same speed range. This may be due higher value of bulk density and penetration resistance of soil during Rabi season.

Effect of Depth of Operation on Draft Force

The relationship between soil depths (5, 8 and 10 cm at 1.5 km/h) and draft forces of furrow openers for Kharif condition are shown in **Fig. 6**. It was found that the draft force is directly proportional to the depth of operation. It increased significantly for all the furrow openers when depth of operation was increased from 5-10 cm. This could be attributed to increase in soil resistance per unit area. The draft force was increased in the range of 0.40-0.45 kgf /cm depth of operation for all the furrow openers. Similar relationships were noticed for Rabi condition (**Fig. 7**).

Soil Disturbance

At different speeds of operation (1.00 to 2.25 km/h), lateral disturbances of soil from center of the furrow are presented in the **Table 3**. It was found that soil disturbances increased with the increase in speed and depth of operation. The soil disturbance was less in the case of inverted - T furrow opener as compared to the shoe and shovel type furrow opener. This was due to smaller boot width.

Seed Emergence

Seed emergences in the plots sown by seed drill with different furrow openers were recorded after 5 days of sowing. The average numbers of seeds sown at a depth of 4-5 cm were 35, 31 and 30 seeds per length for shovel, shoe and inverted - T type openers respectively. The number of plants emerged per meter row length was 60.00 %, 70.96 % and 86.66 %, respectively. The seed emergence percentage was highest in the case of inverted - T type furrow opener. This, again, could be attributed to the fact that the opener could ensure placement of seeds in proper soil moisture environment because it opened a narrow furrow and seed were properly covered.

Conclusions

The following conclusions could be inferred from the results of this study.

1. Seed drill with inverted - T furrow opener requires lower draft, less soil disturbance, higher plant emergence and lowest clogging frequency as compared to shoe and shovel type furrow opener.
2. The performances of seed drill with inverted - T type furrow opener perform better than shoe and shovel type furrow opener in both Kharif and Rabi soil condition.

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Performance Evaluation of a Yam (Dioscorea spp.) Harvester

by

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Abstract

A tractor-mounted yam (Dioscorea spp.) harvester was designed, fabricated and its performance evaluated. The harvester was operated at lift angles of 20^{o}, 22.5^{o}, 25^{o}, 27.5^{o} and 30^{o} at forward speeds of 0.8, 1.6, 2.4 and 3.2 km/h and depths of cut of 46, 48 and 50 cm. These combinations were tested on a factorial basis employing a split - split plot design with two replications and the draft analyzed using analysis of variance (ANOVA) at $P \leq 0.05$. Yam tubers were harvested from rows of ridges of about 58 m long and 1.0 m wide (center to center of furrow). Results showed that draft was significantly affected by the interaction of lift angle, forward speed and depth of cut. The forward speed of 0.8 km/h, depth of 46 cm and lift angle of 20^{o} offered the least draft of 6.9 kN. The harvester forward speed of 3.2 km/h at the lift angle of 27.5^{o} and a depth of cut of 48 cm offered the least damage of 18 % and a high percentage of successfully harvested tuber of 93 %.

Introduction

Yam (Dioscorea spp.) is a staple food for millions of people in West Africa and elsewhere providing an important source of carbohydrate and more protein on a dry-weight basis than is commonly assumed (IITA, 1992). Yam accounts for 4.1 % of the total output of root and tuber crops in West Africa (IITA, 1995) and 26.9 % of the total root crop production in Sub-Sahara Africa (Gebremeskel and Oyewole, 1981; Onwueme and Sinha, 1991). Nigeria alone accounts for 59 % of the world yam acreage and 68 % of the total world production (Onwueme and Sinha, 1991). Nigeria produces about 15 million tonnes of yam annually from 1.4 million hectares. Yam ranks second in terms of total output and area cropped amongst the root and tuber crops (CBN, 1995).

Improvements in yam production have been fraught with difficulties and numerous problems. Principal among these is its high costs, which are a consequence of the heavy labour requirement at planting and harvest, the need for staking (which exposes the leaves to sunlight and reduces their contact with soil pathogens), and sizeable expenditures on seed yams. The present - day methods of production requires the performance of a very large number of tasks such as clearing, planting, weeding, staking, single - or double harvesting and barn preparation. Most of these tasks are performed by hand or hand tools, and may continue to be so for years to come. Some of these tasks are specialized and tend to defy mechanization, of which harvesting is one (Onwueme, 1978). Harvesting by hand is very labourious, tedious and slow. Yam farming requires manual labuor of about 45 mandays per tonne of the harvested crop or 0.10 hectares of area planted (Coursey, 1967). Any strategy aimed at halting the apparent decline in yam production must include new technologies that enable farmers to reduce the cost of production. Mechanization of the various aspects of yam production is one of such strategy.

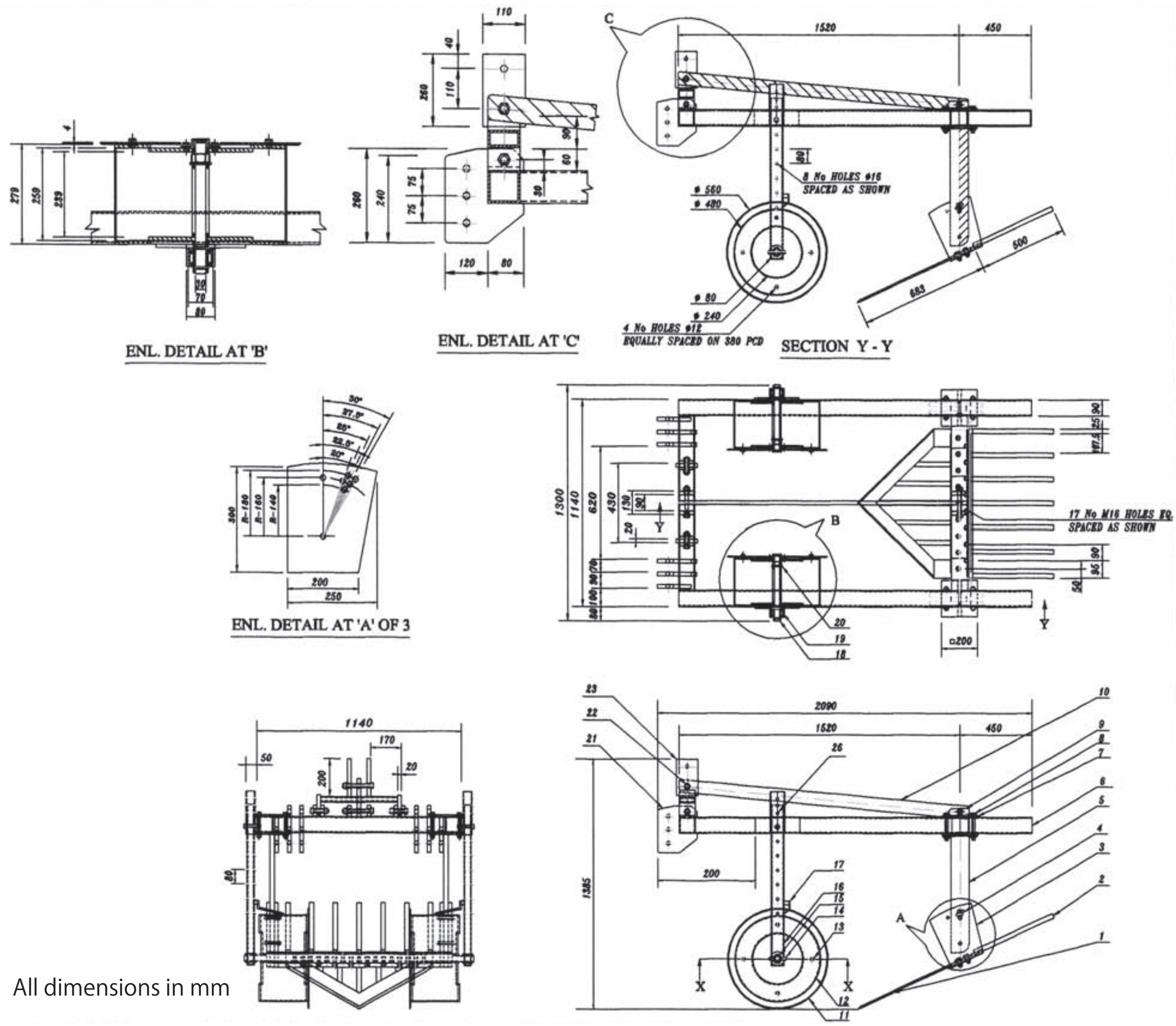
Several factors concerning yam growth and production continue to pose serious problems in attempt to mechanize its harvesting. Apart from the serious difficulties arising from the tuber growth pattern, many yam cultivars produce branching tubers, which are more difficult and more delicate to lift while harvesting. The objective of this study was to evaluate the performance of a designed yam harvester by determining the lift angle, depth of cut and speed of operation that will give the minimum tuber damage.

Materials and Methods

Description of Harvester

Fig. 1 is diagram of the harvester. The yam harvester is mounted on a single row, three-point hitch tractor and shatters the mound or ridge and exposes the tuber for manual picking. The special features of the harvester include the lifting unit [1], depth wheel [12] and tool-bar frame [6]. The lifting unit is a serrated stationary blade [1] that is 82 cm wide and 1 cm thick, positioned 1,300 mm from the hitch point. Projecting from the top of the blade are seven circular bars [2], each of 2.5 cm diameter and 50 cm long to provide the necessary additional lift of mounds and for better separation of crumbled soil from the tubers. The stationary hoe is suspended by two vertical standards [5] that are 82 cm apart and 2.5 cm thick from a main frame [6] and of square cross-section 90 mm x 90 mm, which provides support for all components. Two adjustable gauge wheels [12] of 48 cm each with haulm cutting coulters [11] 56 cm in diameter, located 46 cm from the blade and fixed to the frame. These gauge wheels are used to regulate the depth of penetration of the blade when in operation on the field. The coulters are used to cut away haulms that would otherwise catch the sides of the blade. The coulters are coaxially attached on either side to 4 cm wide circular rims [12] that are 8 cm smaller in diameter. The coulters can cut up to a depth of 4 cm. **Fig. 2** is pictorial view of the harvester.

Fig. 1 Diagram of the yam harvester



1: Lifting blade, 2: Lifting brade rod, 3: Lifting blade holder, 4: Blade holder sector bolt and nut assy., 5: Vertical standard, 6: Main frame, 7: Clamping plate - vertical standard, 8: Bolt and nut assembly, 9: Bolt and nut assembly, 10: A - frame supporting bar, 11: Coulter disc, 12: Depth wheel, 13: Coulter disc bolt and nut assy., 14: Depth wheel shaft nut assy., 15: Depth wheel hub, 16: Depth wheel holder, 17: Scraper blade, 18: Depth wheel shaft, 19: Depth wheel holder bracket, 20: Depth wheel bearing, 21: Lower hitch plate cat II, 22: Bolt and nut assy., 23: A - frame, 24: Stiffner plate vertical standard, 25: Lifting blade bolt and nut assy., 26: Pin

Evaluation of Harvester

The FAO test procedure for the evaluation of agricultural machinery and equipment for primary cultivation was adopted. The harvester was hitched to a 52.2 kW Massey Ferguson tractor that provided the draft power. The lift angle, depth of cut of the harvester and forward speed of the tractor were tested at various combinations on a factorial basis employing a split - split plot design with two replications. The pull at each combination was measured with a Dillion dynamometer. The lift angles investigated were 20°, 22.5°, 25°, 27.5° and 30°. The depths of cut were 46, 48 and 50 cm while forward speeds of tractor were 0.8, 1.6, 2.4 and 3.2 km/h. The evaluation was done by measuring the draft of the five lift angles operated at three depth settings and four speed levels in a split-split plot design with speed as main plot, depth as sub plot and lift angle as sub-sub plot factors with two replications. The evaluation of the harvester was undertaken on yam ridges at the Kaduna Polytechnic farm Kaduna, Nigeria. **Table 1** is the summary of soil conditions for the test site.

Table 1 Summary of parameters for test site

A. Field
1. Location of Field: Kaduna Polytechnic Farm, Kaduna, Nigeria
2. Field size: 0.79 ha
3. Topography: Generally flat to gently sloping, 0 to 2 percent
4. Previous cultivation (& crops cultivated): 1999-uncultivated, 2000-cultivated yam, 2001-cultivated maize & sorghum
5. Soil description: Loam
B. Soil
6. Angle of soil internal friction*: 25.5º
7. Cone penetrometer reading*: 954 kPa
8. Soil shear strength*: 948 kPa
9. Bulk density*: 1.48 g/cm³ at 50 cm depth
10. Soil moisture* (db): 10.89 % at 50 cm depth
C. Harvester
11. Working width of harvester: 82 cm
12. Working depths of harvester: 46 cm, 48 cm and 50 cm
D. Yam
13. Cultivars: cv. Anacha

* Mean values

Draft Measurement and Calibration of Dynamometer

A Dillion dynamometer with 90 N divisions and 22,400 N capacity was used to measure the pull at the various combinations of lift angle, depth of cut and forward speed. The dynamometer was first calibrated using the standard load method so as to adjust the indicated load to the actual load. The dynamometer was loaded with loads of known weights (actual load) from which the dynamometer readings (indicated load) were obtained. The actual load (X) and indicated load (Y) were plotted on a XY scatter diagram from which the line of best fit was drawn and used to obtain a calibration equation (**Fig. 3**).

The dynamometer was placed between two tractors; it was attached to the front of the harvester - mounted tractor and pulled from the drawbar of the auxiliary tractor. Both tractors were 52.2 kW Massey

Fig. 2 Pictorial view of harvesting machine

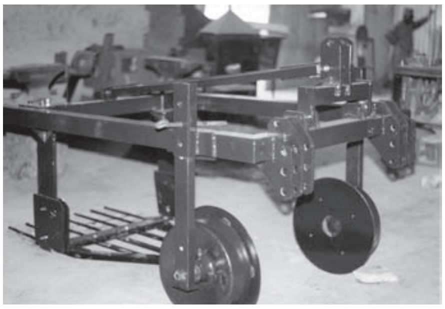


Fig. 3 Calibration graph and equation for the dynamometer

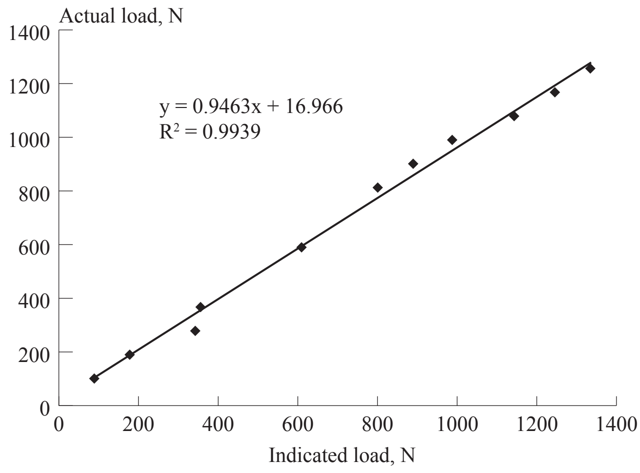
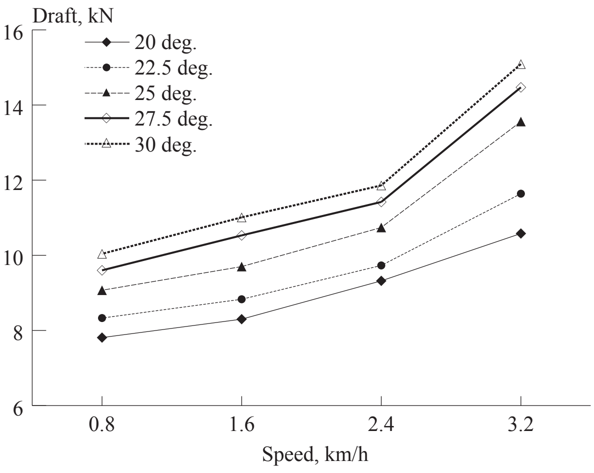


Fig. 4 Comparative effects of speed on mean draft at various lift angles



Ferguson tractors. The auxiliary tractor was used to pull the harvester - mounted tractor through the dynamometer with the harvester set at determined operating conditions and neutral gear position. Readings were taken at approximately every 30 m, along each row of ridge as the harvester moved through the test area. After this reading, the harvester was lifted out of the ground and the reading taken. The difference gave the draft of implement under that operating condition.

Determination of Tuber Damage

One hundred twenty rows of yam tuber ridges of the cultivars Anacha were harvested. The ridges were about 1m apart. Harvesting was done at the lift angles of 20°, 22.5°, 25°, 27.5° and 30°, and depths of 46, 48 and 50 cm at the forward speeds of 0.8, 1.6, 2.4 and 3.2 km/h. Tuber damage was determined by visual inspection and the damages were classified as undamaged, cut and bruised. The numbers of dug, exposed and damaged tubers were analyzed as simple percentages.

Analysis of Results

The ANOVA at $P \leq 0.05$ was used to analyze the measured draft from the various combinations of forward speeds, depths of cut and lift angles. The number of dug tubers (tdt) was determined from equation 1 and the number of completely removed tubers from the ridge and exposed (tct) was determined from equation 2. The percentage of damaged tubers (tdm) was determined from equation 3.

t_{dt} = [No. of tubers dug]/[No. of planted tuber points on the ridge] x 100 %..(1)

t_{ct} = [No. of tubers exposed]/[No. of tubers dug] x 100 %....................(2)

t_{dm} = [No. of damaged tubers (cut & bruised)]/[No. of exposed tubers] x 100 %...(3)

Results and Discussions

Table 2 is the measured draft for the various combinations of harvester share lift angles, depths of cut and forward speeds while **Table 3** is the ANOVA of these results. The least draft of 6.9 kN was obtained from operating the harvester at a lift angle of 20°, depth of 46 cm and a forward speed of 0.8 km/h. This result is similar to those reported by Payne et al. (1956) and Osman (1964). The highest draft of 16.8 kN was obtained from operating the harvester at the share lift angle of 30°, a depth of 50 cm and a forward speed of 3.2 km/h. The least draft occurred at the lift angle of 200 probably because low approach angles aid penetration (Berhane, 1973).

Fig. 4 is the comparative effects of speed on mean draft at the various lift angles. The figure showed that draft increased with increasing speed of operation and lift angle. **Fig. 5** is the comparative effects of depth on mean draft at various lift angles in which the draft increased with increasing depth of cut and lift angles. **Fig. 6** is the comparative effect of depth on mean draft at various speeds. **Fig. 6** showed that draft increased with increasing depth of cut and forward speed of tractor operation. **Figs. 4**, **5** and **6** showed that draft was higher at higher depths of cut, speeds of operation and lift angles.

Table 4 is the result of harvested tuber at the various combination of speed, lift angle and depth of

Table 2 Measured draft (kN) various combinations of share lift angles, depths and speeds

	Depth, cm	L_1 (20°)	L_2 (22.5°)	L_3 (25°)	L_4 (27.5°)	L_5 (30°)
S_1 (0.8 km/h)	D_1 (46)	7.0	7.6	8.2	8.5	8.6
	D_2 (48)	7.9	8.1	8.3	8.5	9.6
	D_3 (50)	8.5	9.3	10.8	11.8	12.0
S_2 (1.6 km/h)	D_1 (46)	7.5	8.0	8.7	9.0	9.1
	D_2 (48)	8.3	8.5	8.7	9.6	10.8
	D_3 (50)	9.1	10.0	11.7	12.8	13.2
S_3 (2.4 km/h)	D_1 (46)	8.3	8.8	9.7	10.0	10.1
	D_2 (48)	9.5	9.6	9.8	10.2	11.7
	D_3 (50)	10.2	10.8	12.7	14.1	13.8
S_4 (3.2 km/h)	D_1 (46)	9.6	10.9	12.7	13.9	14.0
	D_2 (48)	10.5	11.7	13.3	14.3	15.2
	D_3 (50)	11.6	12.4	14.7	15.2	16.0

Table 3 Summary of ANOVA of measured draft

Source of variation	DF	SS	MS	F_{cal}	F_{tab}
Main Plot					
Replication	1	7.21	7.21		
Speed (A)	2	288.14	96.05	465.34*	9.28
Error (A)	3	0.622	0.16		
Sub-Plot					
Depth (B)	2	137.07	68.53	181.64*	4.46
A x B	6	6.68	1.11	2.95^{ns}	3.58
Error (B)	8	3.02	0.38		
Sub-Sub Plot					
Lift angle (C)	4	150.66	37.67	279.98*	2.56
A x C	12	14.680	1.22	9.14*	1.96
B x C	8	16.30	2.04	15.14*	2.14
A x B x C	24	5.74	0.24	1.78*	1.74
Error (C)	48	6.46	0.14		
Total	119	636.560			

* Significant at $P \leq 0.05$, ^{ns} Not significant at $P \leq 0.05$

Table 4 Tuber harvested at the various combination of speeds, lift angles and depths

Speed, km/h	Lift angle, deg	Depth, cm	No. of planted points	Exposed, No. (%)	Cut, No. (%)	Bruised, No. (%)	Cut and bruised, %
0.8	20º	46	50	38 (90.5)	18 (47.4)	5 (13.2)	61
		48	58	43 (89.6)	20 (46.3)	4 (9.3)	56
		50	59	43 (91.5)	16 (37.2)	6 (14.0)	51
	22.5º	46	54	37 (90.2)	18 (48.6)	3 (8.1)	57
		48	62	50 (89.3)	26 (52.0)	4 (8.0)	60
		50	55	40 (88.9)	14 (47.5)	3 (7.5)	43
	25º	46	60	50 (87.7)	23 (46.6)	2 (4.0)	50
		48	60	48 (85.7)	5 (10.4)	13 (27.1)	38
		50	61	48 (82.8)	15 (31.3)	11 (22.9)	54
	27.5º	46	63	47 (90.4)	12 (25.5)	5 (10.6)	36
		48	54	40 (88.9)	8 (22.5)	11 (27.5)	48
		50	63	37 (69.8)	9 (24.3)	7 (18.5)	43
	30º	46	60	38 (86.4)	9 (23.7)	10 (26.3)	50
		48	54	30 (81.1)	5 (16.7)	10 (33.3)	50
		50	61	30 (81.1)	7 (23.3)	7 (23.3)	47
1.6	20º	46	57	44 (91.7)	24 (54.5)	4 (9.1)	64
		48	57	45 (91.8)	26 (57.8)	3 (6.7)	64
		50	63	47 (90.4)	26 (55.3)	3 (6.4)	62
	22.5º	46	63	43 (89.6)	22 (51.2)	4 (9.3)	61
		48	57	40 (95.2)	18 (45.0)	10 (25.0)	70
		50	64	45 (86.5)	23 (51.1)	3 (6.7)	58
	25º	46	54	38 (88.4)	12 (31.6)	7 (18.4)	50
		48	61	46 (88.5)	9 (19.6)	15 (32.8)	52
		50	56	40 (65.1)	9 (22.5)	11 (27.5)	50
	27.5º	46	58	34 (81.0)	8 (23.5)	9 (26.5)	50
		48	60	37 (78.7)	6 (16.2)	13 (35.1)	51
		50	62	33 (73.3)	12 (36.4)	1 (3.0)	39
	30º	46	61	33 (76.7)	3 (9.1)	14 (42.4)	52
		48	59	23 (79.1)	11 (32.4)	6 (17.6)	50
		50	55	27 (73.0)	7 (25.9)	8 (29.6)	56
2.4	20º	46	53	35 (70.0)	11 (31.4)	2 (5.7)	37
		48	62	40 (67.8)	13 (32.5)	4 (10.0)	43
		50	59	42 (73.7)	14 (33.5)	3 (7.1)	41
	22.5º	46	56	38 (76.0)	12 (31.6)	3 (7.9)	39
		48	58	35 (81.4)	10 (38.6)	6 (17.1)	56
		50	61	38 (74.1)	9 (23.7)	4 (10.5)	34
	25º	46	61	47 (85.9)	5 (10.8)	3 (7.9)	28
		48	50	44 (95.7)	8 (18.2)	6 (17.1)	30
		50	55	42 (85.7)	7 (16.2)	4 (10.5)	41
	27.5º	46	62	41 (83.7)	10 (24.4)	8 (17.0)	32
		48	60	40 (78.4)	11 (27.5)	5 (11.4)	35
		50	55	30 (68.2)	7 (23.3)	10 (23.8)	40
	30º	46	55	34 (82.9)	4 (11.8)	3 (7.3)	27
		48	60	35 (81.4)	2 (5.7)	3 (7.5)	37
		50	58	30 (81.1)	3 (10.0)	5 (16.7)	23
3.2	20º	46	58	43 (90.6)	10 (20.8)	3 (6.3)	30
		48	58	50 (89.3)	12 (24.0)	2 (4.0)	28
		50	61	51 (87.9)	11 (21.6)	3 (5.9)	28
	22.5º	46	55	40 (88.9)	10 (25.0)	1 (2.5)	28
		48	60	42 (91.3)	6 (14.3)	8 (19.0)	33
		50	60	45 (88.2)	7 (15.8)	4 (8.9)	24
	25º	46	55	32 (69.6)	3 (9.4)	6 (18.8)	29
		48	55	41 (85.4)	5 (12.2)	4 (9.8)	22
		50	60	37 (75.5)	7 (18.9)	1 (2.7)	22
	27.5º	46	57	37 (77.1)	6 (16.2)	10 (27.0)	43
		48	52	40 (93.0)	1 (2.5)	6 (15.0)	18
		50	58	46 (90.2)	3 (6.5)	14 (31.4)	37
	30º	46	61	33 (80.9)	5 (13.2)	4 (10.5)	27
		48	57	32 (94.4)	5 (15.8)	9 (28.1)	44
		50	61	34 (79.1)	3 (8.8)	8 (23.5)	32

cut. The least tuber damage of 18 % occurred at a forward speed of 1.6 km/h, rake angle of 30° and the depth of 48 cm. A further analysis also showed that the least cut and bruised tubers also occurred at the forward speed of 3.2 km/h with the highest percentages occurring at the speed of 1.6 km/h. The least exposed and harvested tubers were achieved at the speed of 1.6 km/h. The results showed that the least tuber damage (both cut and bruised) and highest tuber harvested occurred at the higher speeds investigated. Conversely, the highest tuber damage and least tuber exposed/harvested occurred at the lower speed. However, no clear pattern was established for the depth of cut and lift angles during harvesting. Results showed the influence of speed on the quality of harvest. Further development of the harvester will be to reduce the tuber damage.

Conclusions

The draft requirement of the harvester was significantly influenced by the combined effect of lift angle, forward speed and depth of cut at which it was operated. The draft increased as the speed, lift angle and depth of cut were increased. The forward speed of 0.8 km/h, depth of cut of 46 cm and the lift angle of 20° offered the least draft of 6.9 kN. The least percentages of damaged tubers and highest successfully harvested tubers occurred at the higher speeds investigated while the highest percentage of damaged tubers and least amount of successfully harvested tubers occurred at the lower speed. The influence of depth of cut and lift angle on the quality of harvest could not be established but that of speed was noticeable. It is recommended that the harvester be operated at the forward speed of 3.2 km/h at the lift angle of 27.5° and a depth of cut of 48 cm, which offered the least tuber

(continued on page68)

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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Anthropometric Survey of Farm Workers in Tamil Nadu: **K. Kathirvel**, Professor and Head, Agricultural Engineering College and Research Institute, TNAU, Coimbatore - 641 003, India; **R. Manian**, Dean, same; **T. Senthilkumar**, Ph. D Scholar, same.

To achieve enhanced performance and efficiency of man-equipment system along with better comfort and safety of operators, it is necessary to design various tools, equipment and work places keeping in consideration the anthropometric data of agricultural workers. Use of anthropometric data can help in the design of equipment for better efficiency and more human comfort. So far the anthropometric data of industrial workers were used and very few inadequate data of farm workers are available for use in farm machinery design. To create a data bank of anthropometry of farm workers a survey was carried out. Tamil Nadu state is divided into 7 Agro-climatic zones and the sample size of 1,500 is divided in proportion to agricultural workers population. In each agro-climatic region/zones the sample size may come to 100 to 500. The data was collected from each district in the agro-climatic zone. The ethnic group/community to which the subject belongs was also noted. The proportion of male and female subjects was 1,000 and 500 respectively. Keeping into consideration the requirements of hand tools, animal drawn implements, tractors, power tillers, power operated machines, self propelled machines and workplaces, a total of 79 body dimensions have been identified and included in the survey. The data include measurement of linear anthropometric dimensions in standing posture (17 Nos.), measurement of transverse distance in standing posture (9 Nos.), circular measurements in standing posture (5 Nos.), vertical measurements in sitting posture for (8 Nos.), measurement of transverse distance in sitting posture (8 Nos.), fore limb measurements in standing posture (18 Nos.), measurements of hind limbs in standing/sitting posture (7 Nos.). Measurements of head dimensions (3 Nos.) and measurements of skin fold dimensions (4 Nos.). Anthropometric measurement of the identified 79 body dimensions of 1,000 male and 587 female farm workers was completed. From the recorded values of body dimensions the mean value, standard deviation. 5th and 95th percentile values were computed and recorded for male and female subjects respectively. The data collected can be used in the design of various farm implements and equipment with respect to anthropometric suitability for enhanced comfort of human subjects. 79. The data bank created will be highly useful to achieve enhanced performance and efficiency of man-equipment system along with better comfort and safety of operators. The data was compared with data available from other states.

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Performance Evaluation of Roto Slasher for Cotton Stalk Shredding: **K. Kathirvel**, Professor and Head, Agricultural Engineering College and Research Institute, TNAU, Coimbatore - 641 003, India; **R. Manian**, Dean, same; **T. Senthilkumar**, Ph. D Scholar, same.

Pulling and collection of cotton stalk manually to the desired extent requires 20 man-days per ha apart from being tiresome and time consuming. The problems faced by cotton growers in the context of removing cotton stalk forcing for mechanization in cotton stalk pulling. The commercially available tractor operated roto slasher (**Fig. 1**) was evaluated for its performance on cotton stalk shredding to enhance the utility of tractors besides reducing the drudgery and eliminating the labour shortage during peak seasons. It is observed that the slashing efficiency of the slasher for slashing cotton stalks is 96.69 %. The percentage of cotton stalks broken and left out during the operation of slasher is 1.85 %. The performance of the unit was compared with the pulling cotton stalks with cotton stalk puller and conventional method of manual pulling. It is observed that the roto slasher operation for shredding cotton stalks resulted in 86.63 and 99.29 percent saving in cost and time respectively and pulling cotton stalks with cotton stalk puller resulted in 3.86 and 94.40 percent saving in cost and time respectively when compared to conventional method of pulling cotton stalks. The field capacity of the slasher is 0.5 ha h^{-1} and the cost of the unit is Rs.55, 000.

Fig. 1 Tractor operated roto slasher

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Assessment of Postural Discomfort of Human Subject during Power Tiller Operation: **K. Kathirvel**, Professor and Head, Agricultural Engineering College and Research Institute, TNAU, Coimbatore - 641 003, India; **Binisam**,

Assistant Professor, Kelappaji College of Agricultural Engineering and Technology, Tavanur, India; **R. Manian**, Dean, Agricultural Engineering College and Research Institute, TNAU, Coimbatore - 641 003, India; **T. Senthilkumar**, Ph. D Scholar, same.

Subjective self reported estimates of effort expenditure might be quantified using rating of perceived exertion. Assessment of postural discomfort includes overall discomfort rating (ODR) and body part discomfort score (BPDS). For the assessment of overall discomfort rating a 10 - point psychophysical rating scale (0 - no discomfort, 10 - extreme discomfort) was used which is an adoption of Corlett and Bishop (1976) technique. To measure localized discomfort (BPDS) Corlett and Bishop (1976) technique was used. Assessments were made at different forward speeds, viz., 1.5 km h^{-1}, 1.8 km h^{-1}, 2.1 km h^{-1} and 2.4 km h^{-1} during field trials and 3.5 km h^{-1}, 4.0 km h^{-1}, 4.5 km h^{-1} and 5.0 km h^{-1} during transport mode of two power tillers with one as walking type (7.46 kW) and the other as riding type (8.95 kW). In general the overall discomfort rating (ODR) scale varied from "moderate discomfort" to "more than moderate discomfort" for both power tillers during rototilling whereas it was scaled as "light discomfort" to "more than light discomfort" during transport mode. The overall discomfort score increased with increase in forward speed for all operations. The ODR and BPDS values were lower for riding type power tiller (power tiller B) than walking type power tiller (power tiller A) for rototilling operation, which is indicative of the fact that the seating arrangement in riding type power tiller reduced the discomfort due to walking. The level of discomfort increased with speed. The intensity of pain experienced by the subjects was more in untilled than in tilled field. The majority of discomfort was experienced in the left arm, right arm, left leg, right leg and shoulder region for all the subjects for walking type power tiller (7.46 kW) during rototilling where as the majority of discomfort was concentrated in the lower back, buttocks, left thigh and right thigh region for riding type power tiller (8.95 kW). It was apparent that pain or discomfort reported in various parts of the body was functionally related to the characteristics of power tiller and type of operation. It was apparent that the seating attachment provided in riding type power tiller B eliminated the drudgery due to walking behind the power tiller A. The results were indicative of the fact that the analysis of body part discomfort score during the actual operating condition can provide information regarding the functional component of the power tiller which could be modified and it was evident that a more ergonomic relationship between operator and machine would permit a less distorted posture and presumably less discomfort.

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Effect of Material and Shape of Tool on Force and Energy Required for Oil Palm Harvesting: **K. Kathirvel**, Professor and Head, Agricultural Engineering College and Research Institute, TNAU, Coimbatore - 641 003, India; **R. Manian**, Dean, same; **B. Suthakar**, Research Fellow, same; **T. V. Job**, Professor, same; T. Senthilkumar, Ph. D Scholar, same.

Harvesting of oil palm consumes major portion of the production cost. Harvesting with conventional tools consumes higher level of energy. The harvesting cost of oil palm can be reduced by increasing the labor productivity. This is achieved by proper design of harvesting tools. Proper systematic designs of tool, skill of the operator and cost effectiveness are the prime factors that necessitate the development of an improved tool. A preliminary survey was conducted and the existing tools used for oil palm harvesting were collected and the shape was defined in terms of the curvature of the cutting edge. Five different curvatures viz. Malaysian model (B_1), Andra model (B_2), Kerala model (B_3), FMD-1 (B_4) and FMD-3 (B_5) made of three different materials (EN-42J (M_1), EN-9 (M_2) and Hardened & Tempered steel (M_3)) were selected. Using all the combination of material and curvature selected, a total of 15 tools were developed and evaluated in the field. The effect of material was negligible since all the five blades required almost same values of maximum cutting force, specific cutting force and specific cutting energy for cutting oil palm frond and harvesting fresh fruit bunches (FFB). But the effect of curvature of blade was predominant. Malaysian model registered minimum value (30.56, 54.5 kgf) of maximum cutting force, maximum specific cutting force (0.26, 0.95 kg cm^{-2}) and maximum specific cutting energy (5.08, 4.78 kg cm per cm^{-2}) followed by improved model (32.56, 55.0 kgf and 0.26, 1.15 kg cm^{-2} and 5.05, 4.50 kg cm per cm^{-2} respectively) for cutting the frond and fresh fruit bunches. All the other blades were found to be ineffective as the curvature of the blades makes the operation tedious by consuming more cutting energy.

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Performance Evaluation of Electrically Operated Curd Beater: **Bharat Bhusan**, Ex-M.Sc. Student, Centre for Food Science and Technology, CCS HAU, Hisar - 125 004, India; **M. K. Garg**, Associate Professor, Department of Agricultural Processing & Energy, same; **B. S. Beniwal**, Milk Distribution Officer, Department of Animal Products Technology, same.

Butter (makkhan) producing in India is an age-old practice. In rural areas, most of the villages produce butter at home level. With the availability of electricity the people have switched over from traditional churner to electrically operated churner. The method of churning is not standardized at rural level. So it was decided to find the best combination of rpm, number of blades and paddle diameter of churner. Milk of six per cent fat was procured and incubated in incubator. Dahi produced was churned using different combination of blades, number of paddles and rpm. Times of churning and power requirement were noticed.

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Processing and Storage of Bambara Groundnut in Northeastern Nigeria: **A. A. Atiku**, Lecture, Department of Agricultural Engineering, Federal Polytechnic Mubi, Mubi, Nigeria; **N. A. Aviara**, Lecture, Department of Agricultural Engineering, University of Maiduguri, Maiduguri, Nigeria; **M. A. Haque**, Professor of Agricultural Engineering and Dean, Faculty of Engineering, same.

A survey of the bambara groundnut scale of production, processing and storage techniques as well as the uses of the crop in Northeastern Nigeria, was carried out. The crop was found to be of economic importance to the communities that produce it, but the scale of production remained low, and the processing and storage methods are still traditional. The pods, which normally develop underground, are harvested by manually pulling up the plant with attendant losses, sun drying of pods are mainly practiced and shelling is accomplished by either pouring them into a jute or hessian bag and beating it with stick or using pestle and mortar or stones to crack them. In some instances, manual treading of the pods on a flat surface is used to shell them. The pods or seeds are stored in pots, bags, and drums or in local granaries. No commercial production and industrial use of the crop takes place in the area study. The study suggests that bambara groundnut harvesting equipment, bambara groundnut sheller and solar drying system, as well as appropriate technology storage facilities should be developed and introduced into Northeastern Nigeria.

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The Level of Agricultural Mechanization in Benue State, Nigeria: **V. L. Umogbai**, Department of Agricultural Engineering, University of Agriculture Makurdi, P.M.B. 2373, Makurdi, Nigeria.

Benue State, which prides itself as the "Food Basket of the Nation", lies between the Southern forest regions and the Northern Semi-arid grassland regions of Nigeria. It has very fertile land for agriculture with an estimated arable land of 1,857,300 ha. In this study, the level of agricultural mechanization in the state is surveyed using structural questionnaires, data obtained from books and manuals and statistical analysis. It was observed that the level of mechanization is 8.22 %, which places the state in the intermediate level of mechanization with human and animal power slightly supplemented with motorized power. The needed machineries are not enough for the estimated cultivated area of 1,182,075 ha. It is recommended that government policies should be geared towards enhancement or participation. Also, the farmers need to strengthen their cooperative organizations for the transfer or credit, equipment hire, dissemination of information on technical know-how and marketing.

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The Use of Draft Animals in Agriculture a Case Study of Plateau State, Nigeria: **V. L. Umogbai**, Department of Agricultural Engineering, University of Agriculture Makurdi, P.M.B. 2373, Makurdi, Nigeria; **E. A. Maigari**, same.

The high cost of tractorised farming in Nigeria calls for alternative sources of energy. In some parts of Nigeria such as Plateau State, animals are used along with tractor. However in most of the rural areas the farmers hardly have access to farm tractors. Such farmers therefore have resulted to farming with animals as a tradition.

The above situation calls for a study of the use of animals by the peasant farmers with the aim of recommending methods of improvement that would lead to higher efficiency and output. This study was carried out in four Local Government Areas (wase, Kanam, Lantang North, and Lantang South) of Plateau State. Questionnaires, physical measurements and observations, and statistical analysis were used for the study.

It was found that in PIateau State, only the white Fulani Bovine (Bunaji) which is locally bred is used for crop production operations. They are generally of the light and medium weights (200 kg to 350 kg). The draft force ranges from 19.3 kgf to 28 kgf at 2.4 km/hr, and from 15 kgf to 21 kgf at 3.5 km/hr. Hours of work are generally from 6:00 am to 11:00 am. A locally fabricated U-shaped metal, encircling the neck is used as yoke for the animals. The animals are predominantly used for ploughing. Virtually no shelters are provided for the animals. Feeding of the animals during the dry season before embarking on the difficult task of soil tillage with the beginning of the rains is poor. Veterinary care is also adjudged inadequate.

It is recommended that specialized and efficient breed of draft animals should be introduced to the farmers. Also, standard yokes and harnesses should be used for higher draft force and efficiency. There is also the need for development of grazing fields and adequate veterinary care. Financial assistance by Government and Non-government organizations (NGOs) to the farmers for care of the animals is recommended.

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Anthropometry of Tribal Agricultural Workers of Northeastern India: **R. K. P. Singh**, ICAR Research Complex for NEH Region, Umiam - 793 103, India; **K. N. Agrawal**, same; **K. K. Satapathy**, same.

In the northeastern hills region of India, most of the agricultural operations are performed manually with the help of animate power sources and traditional tools. Use of improved tools and machinery is very low due to inherited constraints like difficult terrain, wide variation in slopes and altitudes, land tenure systems and cultivation practices. At present traditional hard tools and equipments being used in he region ate manufactured by the artisans and small-scale manufacturers without application of ergonomic considerations. Thus a study was undertaken to develop an anthropometric databese of agricultural workers of Meghalaya. This study presents the anthropometric data of the agricultural workers of Meghalaya, which will help to develop/modify the improved tools and implements suiting to local people of Meghalaya state. Total 769 subjects of five different tribes namely Khasi, Garo, Jaintia, Hajong and Koch from 29 different villages were selected randomly from five districts of the state. Altogether 72 body parameters useful for agricultural equipment design were selected for the study, out of which 63 dimensions were measured in standing posture and the rest were measured in the sitting posture. Body dimensions were recorded using an integrated Composite Anthropometer developed by IIT, Kharagpur, West Bengal. Perusal of data shows that the mean weight and stature of female agricultural worker of Meghalaya is significantly lower than heir male counterpart. The average weight of female workers was found be about 13.6 % lower than the male agricultural workers whereas the average stature of male is nearly 6.4 % higher than the female. Comparison of other body dimensions shows that all the body dimensions of female workers except chest depth and sitting hip breadth are relatively lower than the mate agricultural workers of the state. Moreover, the average vertical reach, vertical grip reach, eye height, illiocrystale height, waist back length, scapula to waist back length, arm reach from the wall, bi-acromial breadth, sitting height, sitting vertical grip reach, sitting eye height, sitting acromial height and hand length of male workers are approximately 7.7 %, 7.9 %, 8.7 %, 5.7 %, 5.0 %, 8.6 %, 5.2 %, 7.4 %, 9.0 %, 9.1 %, 9.7 %, 11.0 %, 11.3 % and 6.8 % higher than the female agricultural workers, respectively. However, there is not much difference in other important dimensions like metacarpal-III height, chest breadth, popliteal height, leg length, etc., which are only abut 2-4 % higher in case of male workers. Comparison has also been made with the available anthropometric data of the agricultural workers of different northeastern states as well as other parts of the country. Through some examples, efforts have been made to illustrate the application of anthropometric data in the design of farm equipments.

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Compatibility of Some Stable Alcohol-Diesel Microemulsions as Compression Ignition Engine Fuel: **Ram Chandra**, Senior Research Fellow, Dept. of Farm Machinery and Power Engineering, G.B.P.U.A. & T., Pantnagar - 263 145, India; **T. N. Mishra**, Professor, same; **T. K. Bhattacharya**, Professor and Joint Director Extension (Engg.), same.

The study determines the feasibility and fuel properties of ethanol-ethyl acetate-diesel microemulsions designated as 200º-10/9/81, 200º-15/9.5/75.5, 200º-20/10/70, 190º -10/22/68, 190º-15/25/60, 190º-20/29/51, 180º-10/35/55, 180º-15/39/46, 180º-20/40/40, 170º-10/43/47, 170º-15/45/40 and 170º-20/50/30 in accordance of Bureau of Indian Standards and Institute of Petroleum. It was found that stable microemulsions prepared from 200º and 190º proof ethanol have their fuel properties somewhat near to that of diesel fuel and can be used as CI engine fuel to supplement 19 to 49 percent diesel fuel during periods of lean supply of diesel in a low bhp constant speed compression ignition engine.

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Effect of Temperature and Blending Concentrations on Properties of Karanja (Pongamia Glabra) Methyl Ester as Fuel for Compression Ignition Engine: **M. K. Verma**, Tech. Assistant G-1, Dept. of Agricultural Engineering, CSKHPKV, Palampur - 176 062, India; **Y. C. Bhatt**, Head, Dept. of Farm Machinery and Power Engineering, CTAE, MPUAT, Udaipur, India.

Energy is the basic pre-requisite for all social and economic activities in all walks of life for existence and development. In the earlier stages of human development the use of energy was confined mainly to renewable sources such as biomass, animal power, wind, water, etc. Most of our present power requirement is fulfilled by fossil fuels such as oil, gas and coal resources and these are continuously under the threat of depletion. Keeping this in view, search for alternate fuel for diesel engine has assumed great significance. Out of all alternative fuel options for diesel, vegetable oils offer an advantage because of comparable fuel properties with diesel and these can be substituted between 20-100 percent. In a country like India, which has shortage of edible oil, main emphasis has to be laid on non-edible oils. The non-edible Karanja (Pongamia glabra) oil was trans-esterified by alcoholysis to reduce the viscosity of oil. Important fuel properties viz. specific gravity, kinematic viscosity and calorific value of Karanja Methyl Ester (KME) and its blends with diesel were determined as per the standard procedures. As compared to diesel, the specific gravity of KME was observed 8 percent higher and kinematic viscosity 2.77 times at 40 ºC. The calorific value was found to be 11.77 percent lower than that of diesel.

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Performance of Animal Drawn Pneumatic Wheeled Multipurpose Tool Frame with Different Attachments: **G. S. Tiwari**, Dept. of Farm Machinery and Power Engineering, College of Technology and Engineering, MPUAT, Udaipur - 313 001, India; **Rajeev Garg**, same.

Despite increasing trends towards mechanisation, the contribution of draught animals in agriculture development cannot be ignored. To make best use of available draught animal power and to increase the working efficiency an animal drawn multipurpose pneumatic wheeled tool frame with wide rims was fabricated. Performance of developed tool frame with different attachments was evaluated at farmer's field in sandy and sandy loam soils using camel and bullocks as a power source. The field performance of multipurpose tool frame with pneumatic wheel was found better as compared to steel wheeled tool frame and indigenous plough used by the farmers.

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Performance of Automobile Discarded Buffed Tyre Used in Camel Carts on Sandy Terrain with Different Rim Widths: **G. S. Tiwari**, Associate Professor, Dept. of Farm Machinery and Power Engineering, College of Technology and Engineering, Udaipur - 313 001, Rajasthan, India; **K. P. Pandey**, Professor, Dept. of Agricultural and Food Engineering, IIT, Kharagpur, India.

Experiments were conducted in indoor soil bin using a single wheel tyre test carriage to predict the performance of automobile discarded buffed tyre of size 10.00-20 with different rim width used in camel carts in sandy terrain of Rajasthan. The selected tyre was mounted, one by one, on the rims of different widths (200, 250 and 300 mm). The performance of the tyre with varying width was assessed at one soil compaction level, five normal loads of 200, 400, 600, 800 and 1000 daN and at five inflation pressures of 69, 138, 207, 276 and 248 kPa. The average ground pressure was assessed on rigid surface and rolling resistance was measured in sand as an important tyre parameters denoting the tyre performance. A 250 mm wide rim was found optimum for use in camel carts.

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The Decreasing of Specific Energy Consumption for Forage Production: **A. Mitroi**, Professor, University of Agricultural Sciences and Veterinary Medicine, Bucharest, Romania; **M. F. Caraveteanu**, Drd., same; **A. N. Udroiu**, Lecture, same; **M. A. Helmy**, Professor, Ag. Eng. Head of Ag. Mech. Dept., Faculty of Ag., Kafr El Sheikh, Tanta University, Egypt.

The Forage production and conservation involve energy consumption for mechanized works. The main kind of energy consumed for the forage grass crop and silo maize is the fuel for tractor engines and self-propelled agricultural machinery.

The determination of fuel consumption in distinct conditions regarding the mechanization technology, the mechanized works and involved equipment, permitted the analyze of specific consumptions and to outline the ways and methods in the reduction of these consumptions.

It was also evaluated the contribution in fuel reduction from fossil resources on environment pollution.

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Anthropometry of Female Agricultural Workers in Kashmir Region: **Jagvir Dixit**, Assistant Professor, Div. of Agricultural Engineering, S.K.U.A.S.T.(K), Shalimar, Srinagar - 191 121, India.

In the present study, Anthropometric and Strength data of female agricultural workers of Kashmir region were collected and compared with the data of other regions of the country and western data. 79 body dimensions and 16 strength parameters were measured from 185 female subjects, chosen randomly from six districts of Kashmir region. It was observed that the mean value of weight and stature for female agricultural workers were 52.7 kg and 153.8 cm respectively. Some small variation was found between the anthropometric data of the Kashmir region and other regions of the country and substantial variation with western data. The engineering anthropometric data collected for the region help in designing/modification and developing improved agricultural machinery for the region to reduce drudgery and improve the efficiency of the machines.

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ERRATA for Vol.38 No.1 2007 Winter issue

Page 68 "Oman Traditional Farms: Changes and Improvement of Farms in Oman"
Author's name: Ahmad Al-Marshudi
Delate "Professor" under Ahmed Al-Marshudi.

NEWS

International Agricultural Engineering Conference

Asian Institute of Technology, Bangkok, Thailand, 3-6 December 2007

Organized by: **Asian Association for Agricultural Engineering (AAAE) and Asian Institute of Technology**

Objective

The main objective of this International Agricultural Engineering Conference is to provide a forum for discussion and information transfer of current developments, achievements and practical applications in all fields of agricultural engineering.

Conference Theme

The theme of the conference is "Cutting edge technologies and innovations on sustainable resources for world food sufficiency".

Subject Areas

Papers are invited in any of the following areas:

- Agricultural engineering education
- Agricultural systems
- Agricultural waste management
- Agro-industry
- Electronics in agriculture
- Energy in agriculture
- Ergonomics
- Food engineering and biotechnology
- Power and machinery
- Soil and water engineering
- Structures and environment
- Terramechanics
- New materials and other emerging technologies including but not limited to:

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

Language

English will be the official language in this International Conference.

Schedule

This International Agricultural Engineering Conference will be held from 3-6 December 2007 at the Conference Center of the Asian Institute of Technology, Bangkok, Thailand. Those who intend to participate can use the attached Expression of Intent Form

Program Outline

The conference is designed for four days. Three days will be allocated for oral and/or poster presentations held in plenary and parallel sessions. Technical tour is scheduled on the fourth day.

Full papers will be published separately in Proceedings which will be available in electronic format while the program and collection of abstracts will be available in hard copies.

Paper Abstracts

Participants who are interested to contribute oral or poster presentations are invited to submit a one-page abstract (up to 500 words) on an A4 size paper. Times New Romans font 12 size, 25 mm all around margin.

The abstract should contain briefly, the introduction, objectives, methodology, key results and conclusion in a short, straight forward 'take home message' . Deadline for receiving abstracts is 1 March 2007. The list of selected paper abstracts will be made available by 1 June 2007.

The format requirements for the full paper will be provided in the second announcement/call for papers.

Technical Presentations

All papers must be presented during the conference. A person can present a maximum of two papers only although he/she can be a co-author or member in other papers which must be presented by another person. Only the papers whose presentors confirmed their attendance through registration by October 2007 will be included in the proceedings.

Each paper will be allocated 20-25 minutes for presentation and discussion. Authors are advised to prepare power-point presentation to suit this duration. A computer, LCD, overhead and slide projectors will be provided.

Important Dates

2nd announcement/call for papers - 1 Dec 2006

Deadline for submission of abstracts - 1 Mar 2007

Notice of acceptance - 1 Jun 2007

Full paper due - 1 Sep 2007

Early registration with payment due - 1 Oct 2007

Conference Venue

The conference will be held in the Conference Center at the Asian Institute of Technology (AIT), Bangkok, Thailand. AIT is an autonomous international institution empowered to award graduate degrees and diplomas. Its 160-hectare beautiful campus is located 42 km north of Bangkok (17 km north of Don Muang International Airport). AIT is easily accessible to other research and academic institutions, factories, historic and tourist attractions, entertainment parks and shopping malls.

Thailand has a tropical climate with three seasons. During the cool season (December to February), the maximum day temperature in Bangkok is about 32 ºC (90 ºF) and a relative humidity is 80 % or higher. Short fierce downpours are common.

Web Page

All details of the conference will be available on the Internet at the following address:

http://www.aaae.ac.th/ae-incon/index.htm.

Further Information

Further details about registration, costs, program and tours will be sent upon receipt of the completed "Expression of Intent" form. For any inquiry, please contact the address below:

The Secretariat
Attn.: Dr. Emmanuel C. Canillas
International Agricultural Engineering Conference
Agricultural Systems and Engineering
School of Environment, Resources and Development
Asian Institute of Technology

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Report on the 35th International Symposium Actual Tasks on Agricultural Engineering

19-23 February 2007, Opatija, Croatia

The 35th International Symposium Actual Tasks on Agricultural Engineering was held on 19-23 February 2007 in Grand hotel "Adriatic" Opatija, Republic of Croatia. The principle Organiser, Agricultural Engineering Department, Faculty of Agriculture, University of Zagreb was supported by the following frameworks: Department of Agricultural Engineering, Faculty of Agriculture, University J.J.Strossmayer, Osijek, Department of Bio-systems Engineering, Faculty of Agriculture, University of Maribor (Slovenia), Agricultural Institute of Slovenia, Hungarian Institute of Agricultural Engineering Gödöllö and Croatian Agricultural Engineering Society. Co-sponsors of the Symposium were CIGR, EurAgEng, AAAE and Association of Agricultural Engineers of South Eastern Europe (AAESEE).

This year 106 participants from 15 countries attended Symposium. It consisted of an Opening Session and six Topic Sessions covering all the broad subject-areas that fall under the scope of Agricultural Engineering. The importance of the Event was underlined by the presence of the Past President of EurAgEng Prof. Daniele De Wrachien, the representatives of the National Societies of Agricultural Engineers of Bosnia and Herzegovina Prof. S. Skaljic, Romania Prof. V. Ros, Serbia Prof. M. Martinov and Prof. M. Djevic and Croatia Prof. Silvio Kosutic.

At the Opening Session prof. dr. Edi Maletic, vice Dean of the Faculty of Agriculture, University of Zagreb and prof. dr. Vlado Guberac, Dean of the Faculty of Agriculture, University J.J. Strossmayer Osijek, made their speeches emphasising the importance of the event and its long tradition. The Convenor, Prof. Silvio Kosutic brought the greetings of the Croatian Society of Agricultural Engineering. Prof. Daniele De Wrachien stressed the long tradition of the Symposia and their future role as one of the main gathering Events for agricultural engineers in South-Eastern Europe, and pointed out the dimension of the tasks and challenges that agricultural engineering education in European universities will have to face and cope with in the third millennium. Prof. dr. Milan Djevic the representative of the Faculty of Agriculture Belgrade, Serbia closed up the Session bringing the greetings of his Faculty to the Symposium's audience. Next, a number of lectures were held, among which are worth mentioning: "Agricultural engineering in South-East Europe, status and prospects " presented by Prof. Silvio Kosutic, "Recent developments of Earth observation techniques for land and water engineering" delivered by Prof. Guido D' Urso, "dTDR as an optimisation tool for advanced process monitoring in biowaste treatment" given by Cornelius Jantschke and "Motion path planning and trajectory computation for a biomass processing robot" presented by Nikica Starcevic.

In the Topic Sessions, each starting with a review report, 52 papers were discussed, in oral presentation. At the Closing Session the Convenor emphasised the role of EurAgEng and CIGR in the ecologically sustainable development of agriculture and in the preservation of cultural heritage within the East-European countries.

During the Symposium round-table Meetings of CIGR, AAESEE, ERA and EurAgEng representatives were held, focusing on the main topics, achievements and trends of the SEEERA Pilot project. The project aims at integrating EU member states and South East European countries by linking research activities within existing national, bilateral and regional R & D programmes. The participants agreed that there is a real need and high time for South East Europe countries, regardless to their recent status, to strongly enhance research cooperation by fostering integration of South East Europe into the growing European Research Area.

World famous agricultural machinery producers, such as AGCO, Case-New Holland, Claas, Hardi and others presented their current programmes by means of video and oral presentations during afternoon Sessions.

Information regarding the 36th Symposium in the year 2008 will soon be available at the web site: http://www.agr.hr/aed/index.htm

Prof. Silvio Kosutic, Convenor of the Symposium
Prof. Daniele De Wrachien, Past President of EurAgEng

Dr. Megh R Goyal, a co-editor for AMA, was Declared as Man of Drip Irrigation in Puerto Rico

Secretary of Agriculture, Senate, Governor, and Mayors of municipalities of Ponce, Caguas, Mayaguez of Commonwealth of Puerto Rico have declared Megh R Goyal, Ph.D., P.E. (Fourth from left) as "Man of Drip Irrigation in Puerto Rico" at the first congress on "Drip Irrigation in Puerto Rico" on April 2, 2007.

VDL Cultivit Machine Beats Soil Steaming

In radish crops (Raphanus sativa L.) in the Netherlands Steam sterilisation of Soil against the fungal pathogen Fusarium oxysporum f.sp. conglutinans is common practice. The costs of soil steaming however have increased rapidly over the last years. Moreover after steam sterilisation the soil is very wet. This is unfavourable for the next radish crop. To offer an alternative VDL Cultivit developed a machine under the name Cultivit®, which exposes soil particles to hot air of approximately 800 ºC during rotary spading. Main advantages of this method are a considerably lower cost price and more ergonomic working conditions. Moreover the soil stays dry and planting or sowing can take place directly after treatment.

Independent Research

In spring 2007 comparative trials have been performed by the independent research institute "Applied Plant Research" of "Wageningen University and Research centre". These trials were performed at a radish nursery in 's Gravenzande in the Netherlands on sandy soil which was infested with Fusarium. Three methods were taken into account: treatment with Cultivit®, soil steaming and an untreated reference. The results show that the Cultivit® treatment gives a significantly higher yield compared to soil steaming. The Cultivit ® treatment gave a 27 % yield increase and soil steaming a 17 % yield increase compared to the untreated reference. Also in a visual judgement the tubers treated with Cultivit® got the highest ratings and on the subjects leaf length, Leaf colour, earliness and tuber uniformity Cultivit® scored best.

VDL Groep

VDL Cultivit B.V. is part of the successful company VDL-Groep from the Netherlands. VDL Groep, with its head office in Eindhoven, is an international company focused on the development, production and sales of semi-manufactured and finished products. In total, the group, with approximately 7,300 employees, consists of 75 subsidiaries spread over 14 countries.

In the supply sector, VDL specialises in metalworking, plastics processing, system supply and surface treatment. The bus & coach division includes coaches, chassis modules, public transport buses, mini and midi buses. The finished products sector comprises suspension systems for the automotive industry, production automation systems, heating, cooling and air-technical systems, systems for the oil, gas and petrochemical industry, sunbeds and roof boxes, products for intensive livestock keeping, tube systems, cigar-making and packaging machines, container handling equipment, medical systems and production systems for optical media.

VDL Cultivit bv
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http://www.vdlcultivit.com/

University of Melbourne E-Prints

The Mechanics of Fluid - Particle Systems with special reference to agriculture

Theory and Worked Examples. A book for engineers and engineering students.

Ross. H. Macmillan
Senior Fellow in Agricultural Engineering, International Development Technologies Centre, University of Melbourne, Parkville, Victoria, 3052, Australia
r.macmillan@devtech.unimelb.edu.au

This book is available free of charge and can be down-loaded from the University of Melbourne web site:

http://eprints.unimelb.edu.au/archive/00001514/

Following the introductory review in Chapter 1, the interaction of bodies and fluids moving with a relative velocity is considered in Chapter 2. This is illustrated by the drag coefficient - Reynolds number relationship for bodies of various shapes and for some agricultural materials.

In Chapter 3 the concepts of terminal and floating velocity are introduced and their application as a basis for the separation of two fractions in a mixture is discussed.

Chapter 4 introduces the two - dimensional, general solution to the fluid - panicle trajectory problem and explains the basis of the algorithm on which the associated computer Trajectory Plotting System program is based.

Chapters 5 to 16 detail a number of applications of the program in agricultural engineering and associated technologies. Chapters 9 and 13 are reserved for future use.

Total pages - 155

Note: no printed versions of this book are available; it must be down-loaded from the University of Melbourne web site at the above address.

Trajectory Plotting System

A general purpose computer program for plotting trajectories of particles moving relative to fluids.

Ross. H. Macmillan
Senior Fellow in Agricultural Engineering, International Development Technologies Centre, University of Melbourne, Parkville, Victoria, 3052, Australia
r.macmillan@devtech.unimelb.edu.au

This program is available free of charge and can be down-loaded from the University of Melbourne web site:

http://epronts.unimelb.edu.au/archive/00001513/

The computer program plots the trajectories of up to 10 particles released with a user defined (including zero) velocity into a fluid stream with a user defined (including zero) velocity, both at any angle. The trajectories may be plotted in x - y, x - t or y - t formats; the end results are presented.

Constant and variable fluid-stream conditions can be specified. The fluid properties are specified by density and absolute viscosity and the particle properties by its mass and equivalent diameter.

The program uses the drag coefficient - Reynolds number relationship for spheres as the default but user specified values for other shapes can be loaded, used and stored.

The program is a Microsoft Windows application in the Delphi programming language to run on Windows 95/98/ME/NT4+/2000/XP.

An on - line Users' Manual is available at the same site.

Note: no CD copies of this program are available; it must be down-loaded from the

University of Melbourne web site given above.

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B Kayombo


M F Fonteh


A A K El Behery


A M El Hossary


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I K Djokoto


D K Some


K Houmy


J C Igbeka


E U-Odigboh


K C Oni


N G Kuyembeh


A H Abdoun


A B Saeed


A I Khatibu


E A Baryeh


S Tembo


H A Cetrangolo


I de A Nääs


A E Ghaly


E J Hetz


A A Valenzuela


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O Ulloa-Torres


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A M S Al-Amri


S F Chang


T S Peng


S Krishnasreni


S Phong-supasamit


C Rojanasaroj


V M Salokhe


Y Pinar


I Haffar


N Hay


P V Lang


A A Hazza'a


A P Kaloyanov


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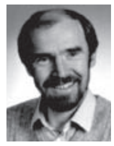
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G Pellizzi


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Jan Pawlak


O S Marchenko


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M Martinov

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