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# AMA

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VOL.40, No.1, WINTER 2009

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FARM MACHINERY INDUSTRIAL RESEARCH CORP.

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YOSHISUKE KISHIDA

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## EDITORIAL

We are faced with the worst economic situation we have ever experienced. With sub prime loan bankruptcy as a start, our financial system, which is one of the most important structures in a capitalistic economy, fell into a critical situation. Such failure in the financial system has caused great damage to the world economy.

Not being a resource producing country, Japan imports the resource and exports the processed goods. With world-wide depression, Japan's foreign trade, which depends largely on foreign demands, has fallen into a critical situation.

How long this recession will continue looks to be a tough question even for most economic experts. The world political and financial leaders assembled at the G7 and G20 meetings to discuss measures to get over the present recession but failed to come to a positive conclusion. Many people have already been thrown out of work and the employment situation is going to be worse.

Toyota Motor Corporation, having been one of the most successful companies in Japan, got into the red by over 500 billion Yen this term, whereas, they had a record-breaking profit of over 2000 billion Yen just a year ago. Even the great car manufacturer, General Motors, is now forced to the verge of bankruptcy.

I consider that we must overcome the present economic crisis before we can get the whole economic system back in the right direction. Over the past years economic prosperity has been supported by excessive consumption within a high-consumption society, which has put heavy pressure on the ecological system, causing the destruction of forests and other nature systems. With this recession as a turning point, new sustainable economic systems must be built on a global basis. What we need now is to put the economic system in harmony with the ecological system that will extend far into the future. If the present difficulties provide us with a good opportunity to reconsider our way of living or economic activities, the recession will prove to be a good signal for mankind.

I have repeatedly stated my view that we can live a sustainable life only when living in harmony with the ecological system around us. As a result of our working on the ecological system in pursuit of more complete harmonization with it, we have been blessed with food, fiber, lumber, beautiful forests, plentiful natural environment, fine water and even a spiritual healing for human beings.

Appropriate improvements on eco-systems require appropriate tools, and agricultural machines are one of the most important tools. Agricultural machinery experts should give special thought on how agricultural machines can serve for building new economic systems. Every effort should be made to develop more appropriate machines and to promote wide use of agricultural machines... It is our mission and dream to realize more favorable harmonization with ecological systems through agriculture and its mechanization.

**Yoshisuke Kishida**  
Chief Editor

March, 2009

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# Comparative Evaluation of Different Groundnut Digging Blades

by

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## Abstract

The performance of three types of groundnut digging blades, namely; straight, inverted V and crescent shaped were evaluated. The results show that the straight type blade had lower average draft force with maximum harvesting efficiency. The draft force required by the straight blade was 175.82, 184.82 and 199.96 kg, respectively, at 10, 15 and 20 deg rake angles. The draft force requirement for inverted V blade was 188.52, 196.96 and 206.74 kg while for crescent shaped blade was 206.30, 212.63 and 222.70 kg, respectively, at 10, 15 and 20 deg rake angles. The maximum harvesting efficiency was 98.93 percent for straight blade, 97.64 percent for inverted V blade and 97.38 percent for the crescent shaped blade at 15 deg rake angle. For the design of simplicity, straight type blade was the best and should be used as a digging blade in groundnut harvesting machine.

## Introduction

Groundnut (*Arachis hypogea* L) is a major oilseed crop produced in commercial scale in India, Nigeria, and USA. The groundnut production in India is 18 percent of the total production with a productivity of 924 kg per ha as compared to the worlds average productivity of 1,449 kg per ha (Annon, 2000). The productivity of oilseed crops in India can be improved through the adoption of viable technologies in the mechanization of groundnut cultivation suitable to the Indian condition.

The current digger types have many blades, each with some advantages and disadvantages, depending on blade type, working situation and conditions. Awadhwal et al. (1995), reported that a chisel digger was designed and developed at ICRISAT Asia Centre, for harvesting groundnut crop. The digger had two shares inclined at 1,200 to each other and contained chisel points for increased penetration in to the soil. Gupta and Parmar (1991) stated that a new

groundnut harvester blade was developed and tested. It cut deeper, leaving a minimum number of pods in the soil and reduced harvesting losses by approximately 47 %.

In spite of the stress on the importance of the blade type in the designing operation, the amount of loses, draft and degree of soil penetration and disturbance, least efforts have been done to investigate a suitable blade which is more reliable. The objective of this study was to investigate and select the most efficient blade design for digging groundnut.

## Materials and Methods

Field experiments were conducted in red sandy loam soil to evaluate the performance of the different groundnut digging blades, namely; straight, inverted V and crescent shaped under different soil moisture conditions and machine parameters related to harvesting.

The soil parameters namely soil

type, soil moisture, bulk density and cone index were analyzed. Experiments were conducted at three different moisture levels, viz 15.50, 12.50 and 10.50 percent, respectively, after irrigating the field 2, 4 and 6 days prior to harvest. The mean bulk density was 1.47 g/cm<sup>3</sup>. The cone index was measured by using a Vicksburg cone penetrometer at a depth of 0-10 cm at ten different places selected at random during harvest. The highest value of cone index was about 1.63 kg/cm<sup>2</sup> at the soil moisture of 10.35 percent. Experiments were conducted for the harvesting of the CO 1 and TMV 2 varieties of groundnut. The maximum depth of pod below the soil surface occurred in CO 1 variety with a value of 67.0 mm where as it was 62.0 mm in TMV 2. The maximum depth value was used in fixing the depth of operation of the tool in the soil.

The levels of parameters, namely; tool geometry, width, length, approach angle, rake angle and operational parameters such as depth and speed of operation were optimized with the help of experimental setup made as an attachment to the power tiller. The shape of tool penetrating and loosening the soil has a direct effect on the force required to pull the tool for easy flow of soil and crop over the surface of the blade (Klenin et al., 1985). Three types of tools, viz. straight shaped, inverted V shaped and crescent shaped (Fig. 1) were used to study the effect of tool shape. The depth of penetration at the centre as well as at the ends was governed by the inversion angle of the tool known as approach an-

gle. The approach angle of zero deg was selected in case of straight tool and 15 degrees in case of inverted V shaped and crescent shaped tools for the study considering the soil tool interface interaction and penetration depth parameters (Duraisamy, 1997). The soil resistance increased with tool width due to the increase in soil contact area (Payne, 1956). Hence, tool geometry with 6 mm thickness and 6.5 cm width was used throughout the study. The front edge top face was tapered to have a taper angle of 15 deg in all the tools (Gupta et al., 1989). Normally, row-to-row spacing of most of the groundnut varieties varies from 22.5 to 30 cm. Hence, the tool length of 50 cm was selected in order to cover two rows. The lower levels of the rake angles (the suction angle of the soil-tool interface measured along the direction of the travel with the horizontal soil surface) were selected for the study (Chase, 1942 and Bosoi, 1990). Hence, three levels of rake angles viz. 10, 15 and 20 degrees were selected for the study. The operating speeds of 1.5, 2.0 and 2.5 kph were selected for the study. The depth of operation was 10 cm for all the experiments within which all the pods remained in the soil in all the varieties (Daniel Sundarraj and Thulasidas, 1993).

The effect of tool geometry on the draft requirement in combination with moisture and rake angle is presented in Table 1. The dynamometer calibration (Fig. 2) was carried out to determine the response of dynamometer to the load applied. The draft requirement was steadily increased with the decrease in soil moisture level for all the three types of tool geometry. This might be due to the more soil resistance due to decrease in soil moisture from 15.5 to 10.5 %. The increase in rake angle in all the three types of tool geometry increased the draft of the tool because of increase in soil resistance as the increase in rake angle increased the soil contact area (Harrison, 1982). The draft required was minimum for the straight tool while it was maximum for crescent tool at all the levels of rake angle and soil moisture under the study. The minimum draft of 156.56 kg was required at 10 deg rake angle and 15.5 percent soil moisture for the straight tool, where as the maximum draft of 253.22 kg was required at 20 deg rake angle and 10.5 percent soil moisture for the crescent tool.

The harvesting efficiency, also,

## Results and Discussion

The performance of the three types of groundnut digging blades was evaluated in terms of draft requirement and harvesting efficiency at the different levels of factors.

Fig. 2 Calibration chart of hydraulic dynamometer

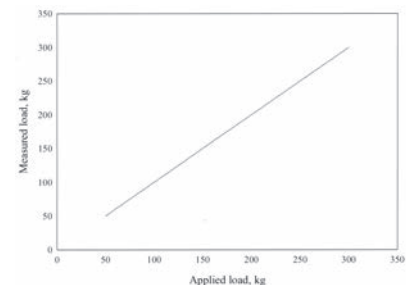
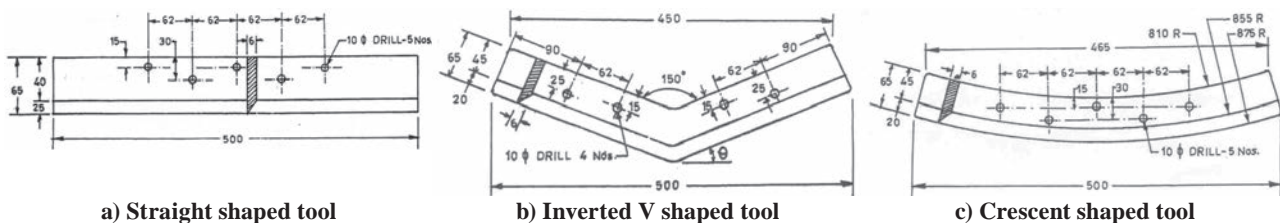


Fig. 1 Types of tool geometry



was significantly affected by tool geometry and rake angle and given in **Table 2**. It was observed that the harvesting efficiency was maximum at 15.5 percent soil moisture while it was minimum at 10.5 percent soil moisture. The harvesting efficiency was increased from 96.43 to 98.93 percent for straight and 95.41 to 97.64 percent for inverted V shape, whereas it was increased from 95.24 to 97.38 for crescent tool when the soil moisture level was increased from 10.5 to 15.5 percent. The maximum harvesting efficiency was 98.93 percent for straight blade, 97.64 percent for inverted V blade and 97.38 percent for the crescent shaped blade at 15 deg rake angle.

## Conclusion

The draft was decreased with soil moisture and increased with rake angle and forward speed for all the three types of blades. The minimum

draft of 156.56 kg was obtained for straight tool at the combination of 10 deg rake angle and 15.5 percent soil moisture. The maximum draft of 253.22 kg was obtained for crescent shaped tool at the combination of 20 deg rake angle and 10.5 percent soil moisture. The straight shaped tool was selected as best tool for harvesting of the groundnut, which gave the maximum harvesting efficiency at the minimum of the draft.

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**Table 1** Effect of tool geometry on draft

M × G × A Table of means for draft of the tool, kg

Rake angle (A), deg	Soil moisture (M), percent			A-Mean
	10.5	12.5	15.5	
<b>G = Straight</b>				
10	193.44	177.44	156.56	175.82
15	199.44	194.44	160.56	184.82
20	208.00	198.11	193.78	199.96
<b>G = Inverted V</b>				
10	202.11	193.89	169.56	188.52
15	213.89	202.89	174.11	196.96
20	215.67	214.78	189.78	206.74
<b>G = Crescent</b>				
10	227.56	210.22	181.11	206.30
15	241.89	211.11	184.89	212.63
20	253.22	217.00	197.89	222.70
M-Mean	217.25	202.21	178.69	199.38

**Table 2** Effect of tool geometry on harvesting efficiency

G × A Table of means for the harvesting efficiency, percent

Tool geometry (G)	Rake angle (A), deg			G-Mean
	10	15	20	
Straight	97.06	98.93	96.43	97.47
Inverted V	95.66	97.64	95.41	96.24
Crescent	95.49	97.38	95.24	96.04
A-Mean	96.07	97.98	95.69	96.58



# Designing and Testing an Improved Maize Sheller

by

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## Abstract

One factor that causes grain damage and broken corncobs using local maize shellers in Indonesia is the fixed arrangement of the concave component. This arrangement means that high energy (6.5-8.5 hp) input is required for the shelling process.

The objective of this study was to develop a new power sheller that could reduce grain damage and broken corncobs. The basic principal of this new mechanism was the reduction of the normal stress during the shelling process by developing a concave system that could vibrate without causing great impact on the maize grains. To do this, the concave system was suspended using a rubber spring to minimize impact. This prototype used a 7.0 hp gasoline engine. The corn used for the prototype performance test had 24 % moisture content wet basis (w.b.). The Student t-test ( $p = 0.05$ ) was used to evaluate the performance of the new prototype, called SENAPIL, as compared to SLM (local maize sheller operated with 6.5 hp diesel engine). The performance test showed that SENAPIL's effective capacity (4.82 t/h) was significantly higher than the SLM's effective capacity (2.57 t/h). In addition, broken corn cobs and grain damage decreased from 96.63 % to 35.18 % and from 12.33 % to 5.04 %, respectively. However, the grain loss in terms of unshelled grain increased from 0.24 % to 1.62 %. Consider-

ing all these technical parameters, SENAPIL still had higher feasibility for application at the farm level than the SLM sheller, with a unit cost of Rp 1.6/kg, breakeven point of 153 t, payback period of 0.3 year, net present value of Rp 11.0 million, benefit cost ratio of 2.6 and internal rate of return of 299 %. SENAPIL was patented in Indonesia in 2003 with patent number ID 0 000 446 S.

## Introduction

In Indonesia, East Java contributes about 42 % of the national corn production (Laumans et al., 1985). To maintain this contribution, it is imperative to increase the efficiency of the shelling process of the local maize sheller operated in the village cooperatives (KUD), which is one of the important agencies in grain postharvest handling and food procurement in Indonesia.

During the 1980-1990 decade, many efforts were made to improve the performance of local shellers in the Philippines as well as in Indonesia. In the Philippines, the National Postharvest Institute for Research and Extension (NAPHIRE) developed an improved maize sheller with a capacity of 2.0 t/h, a breakage of 1.89 % and an unshelled loss of 0.13 %, when shelled at 25-29 % moisture content (Manebog and Gregorio, 1986). This maize sheller used a 12 hp diesel engine or 16 hp gasoline

engine. The effective capacity was only 125 kg/h/hp With the gasoline engine and 167 kg/h/hp with the diesel engine. An improved pedal sheller called RAMAPIL that was developed by the Research Institute of Legume and Tuber crops (RILET) in 1990 had a capacity of 200 kg/h/man (Tastra, 1992). With one man-power equal to 0.04 kW (or 0.05 hp) (Moens, 1978), the RAMAPIL's effective capacity was 4,000 kg/(hp h). Thus, in terms of energy input, the improved mechanical sheller was less efficient than RAMAPIL. Similarly, an improved mechanical sheller operated in the main maize producing area of Kediri, East Java Province, Indonesia, also had low efficiency in terms of energy input for the shelling process. The capacity (383 kg/h/hp-diesel engine) was higher than that of the NAPHIRE sheller. However, the latter had higher grain damage (13 %) and unshelled loss (0.24 %) than the NAPHIRE sheller. In summary, each improved mechanical sheller had a specific advantage.

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Although each improved mechanical sheller had a specific advantage, all have the same limitation in terms of broken corncobs produced. A performance test of local maize shellers conducted in 1989 in the working area of Nugroho village cooperative (KUD) showed that all maize shellers produced a high proportion of

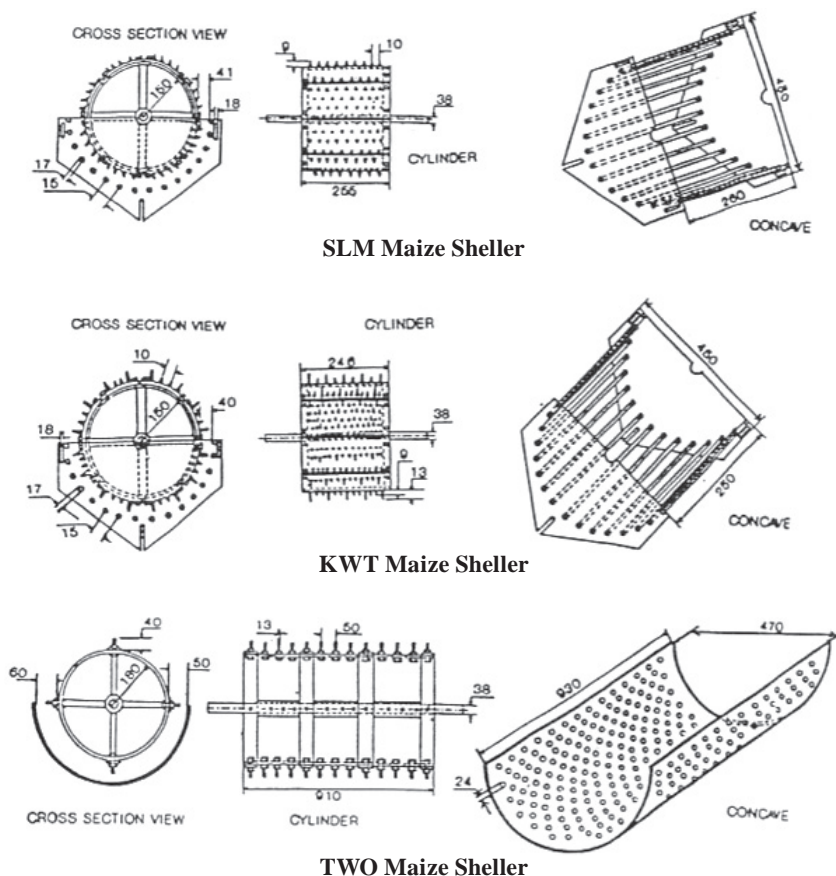
broken corncobs. At 24-29 % w.b. grain moisture content, the percentage of broken corncobs was between 92-100 % (Tastra, 1989). No data exist on broken corncobs produced by the improved NAPHIRE sheller. It was concluded from the pilot testing of that sheller in the Philippines that broken corncobs were one of the

social constraints to adapting/utilizing the sheller since the target users prefer the preservation of whole cobs as an alternative source of fuel for cooking (Manebog et al., 1989).

One factor causing the high proportion of broken corncobs and grain damage is the fixed arrangement of the concave component used in all local maize shellers operated in the working area of KUD Nugroho. One effect of this type of concave arrangement is the high energy input required for the shelling process. All local maize shellers should be operated using 6.5-8.5 hp diesel engines. Most of this energy, in fact, is used inefficiently as indicated by the high proportion of broken corncobs (90-100 %) (Tastra, 1989). Therefore, some investment cost to buy the expensive diesel engine is loss. In addition, due to the high grain damage the price of shelled corn was also reduced by Rp 0.6/kg shelled corn for each 1 % increment of grain damage (Purwadaria, 1989).

Cognizant of the significant impact of broken corncobs on the adoption of a mechanical sheller, grain damage on price reduction and high energy input on high investment cost, it was still necessary to improve the performance of mechanical maize shellers operated in primary maize producing areas. Therefore, the objective of this study was to develop an improved power sheller that could reduce grain damage, broken corncobs and energy requirement for the shelling process.

**Fig. 1** Schematic diagram of the cylinder and shelling concave component of the three local maize shellers. Representative shellers are named according to the name of the owner of the sheller (SLM: Mr. Slamet, KWT: Mr. Karwinto and TMO: Tomo). Technically, all shellers produced by local workshops were cylinder type shellers. All dimension are in mm.



**Table 1** Performance test of local shellers operated in the working area of the KUD Nugroho Kediri, E. Java, Indonesia (Tastra, 1989)

Sheller type <sup>1</sup>		Capacity, t/h	Grain damage, %	Grain loss, %	Broken cobs, %	Grain moisture, % w.b.	Fuel, l/h/hp	Power sources <sup>2</sup> , hp
SLM	Mean	2.57	12.33	0.24	96.63	24.00	0.08	6.50
	SD	0.05	2.10	0.08	1.09			
KWT	Mean	3.29	7.01	1.30	92.08	29.00	0.11	6.50
	SD	0.01	0.77	0.27	1.61			
TMO	Mean	1.90	9.95	0.00	100.00	29.00	0.12	8.50
	SD	0.21	1.15	0.00	0.00			

<sup>1</sup> Classified based on the name of the owner of the shellers (Fig. 1), <sup>2</sup> Diesel engine

## Methodology

To achieve the objective of this study, three representative shellers operated in the working area of KUD Nugroho, East Java province, Indonesia were tested in 1989. The schematic diagram of the concave-cylinder arrangement of the maize shellers is presented in **Fig. 1** and their performance test results are presented in **Table 1**. Based on tech-

nical evaluation (especially on the construction of the concave-cylinder arrangement) of those shellers, a new mechanism power sheller was then designed in the Research Institute of Legume and Tuber crops (RILET) from August 1991 until January 1992 and tested at the village of Tlogosari, South Malang, East Java province, Indonesia, in February 1992.

### Basic Mechanism of the New Power Sheller

The basic principal of the new maize sheller was reduction of the normal stress during the shelling process by developing a concave system that could vibrate (Fig. 2). To do this, the concave component was suspended using a rubber spring that had both viscous and spring characteristics. In addition, it could be easily found at the village level. The distance between the concave component and the cylinder could be adjusted using front and back adjustments depending on the diameter of the maize cobs being shelled. With this new mechanism, the maize grain would be shelled, not only due to cylinder rotation, but also due to the vibration and the damping effect of the concave system. This damping effect could minimize the normal stress on the maize grain being shelled and the proportion of broken corncobs.

### Design Description of the New Power Sheller

Figure 3 shows a schematic view of the power maize sheller (A), cross sectional view of the shelling cylinder and the vibrating concave arrangement (B), a view of the shelling cylinder component (C) and a view of the vibrating concave component (D). The number in the circle identifies the specific component in the design of the power sheller.

As shown in Fig. 3, the power maize sheller consisted of two main components a shelling cylinder (16) and a vibrating concave component (14). The shelling cylinder (16) was made from a wooden cylinder (30), shelling teeth (15) were made of 8 mm dia. iron rod welded on a 4 mm strip plate (22), AS (iron rod) dia. 19 mm (18), lager (17), V-pulley 230 mm dia. (13) and a flywheel (10). The number of shelling teeth (15) per row was 16 and 17, which were welded on the strip plate not in parallel position. There were a total of 12 rows of shelling teeth (15). A strip plate (27) was used to combine the wooden cylinder (30) with AS (iron rod) 19 mm dia. (18).

The vibrating concave (29) was made of 8 mm dia. iron rod welded on a strip plate (20) 4 mm thick with a spacing of 3.5 cm and with an 8 mm dia. iron rod (21) with spacing of 3.0 cm. A hook (23) was added to hang the vibrating concave that used

a rubber spring (13) and a chain (19) with a nut (24) to maintain the space between the shelling cylinder and the vibrating concave system. By combining the tension of the rubber spring (13) and the chain (19), the space between the shelling cylinder and the vibrating concave system could be set based on the diameter of the husked maize cobs being shelled (28).

Power was transmitted to the two main components by a 127 mm dia. V-pulley (25), 230 mm dia. V-pulley (3) and two B-type V-belts (4). The frame (12) of the two main components was combined with two motor cycle wheels (6). The frame also held a hopper (1), a cob resistor (31), a hook for setting the rubber spring (26), a component (7) for setting the vibrating concave system (14) with the cylinder (16) and an iron cover plate (8).

The synergic action of the shelling cylinder component (16) with the vibrating concave component (14) could increase the shelling effectiveness and reduce grain damage (Tastra, 1983). This was due to low impact on maize being shelled by using the vibrating concave component (14) that was attached with a rubber spring (13). In addition, the viscoelastic properties of the rubber spring (13) used for hanging the vibrating concave component (14) resulted in more evenly distributed

Fig. 2 Schematic of the new mechanism power sheller called SENAPIL

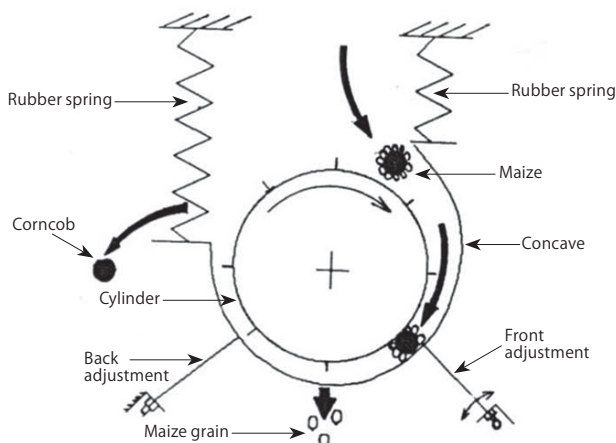
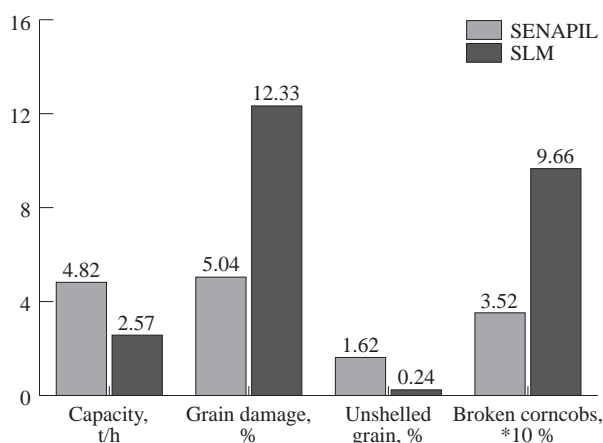


Fig. 4 Performance of the new power sheller (SENAPIL) and the local sheller (SLM)



friction on maize cobs (28) during the shelling process.

The 8 mm dia. iron rod vibrating concave system was welded onto a strip plate (20) that directed the husked cobs (28) so that the shelling process followed a spiral-wise path. This reduced the shelling workload since the shelling process started gradually from one edge of the husked cobs. The high contribution of the vibrating concave component (14) was obtained by transmitting the engine power (5) with a V-belt (4) and pulley (3, 25) through the shelling cylinder (16). Due to the important function of the shelling cylinder (16) in the initial shelling process, the edge of the shelling teeth (15) were not made so sharp.

The sheller had two wheels (6) for easy mobility. When the sheller

was moved a short distance, the handle (11) of the sheller was held and pulled by hand of the operator. For long distances, the sheller was pulled by motor cycle.

The shelling process conducted by two operators was done by feeding husked cobs into the hopper (1) after the cylinder speed reached 700-900 rpm. Due to the rotation of the shelling cylinder (16) and the friction of the vibrating concave system (14), maize was shelled. The shelled grain fell through to the grain outlet (9), while the cobs fell through the cob outlet (2).

### Performance Test of the New Power Sheller

During the field test the prototype was powered by a 7.0 hp gasoline engine that was less expensive than

a 6.5 hp diesel engine. The moisture content of the corn was 24 % w.b. Comparison of the prototype (SENAPIL) with the SML (local corn sheller with a with a 6.5 hp diesel engine) was made with the Student t-test ( $p = 0.05$ ). Comparison was made at the same grain moisture level for effective capacity (EC t/h), unshelled corn (UNC %), grain damage (GD %) and broken corncobs (BRC %). (For explanation of other abbreviations used in the following equations refer to **Appendix 1**.)

The technical performance parameters are defined as:

$$EC = (SC / TPS) \times 3.6 \dots\dots\dots(1)$$

$$UNC = [HSG / (HSG + SC)] \times 100 \% \dots\dots\dots(2)$$

$$GD = (WGD / WS) \times 100 \% \dots\dots(3)$$

$$BRC = (WBRC / WOTC) \times 100 \% \dots\dots\dots(4)$$

### Financial Analysis

Financial evaluation was based on undiscounted measures such as cost per kg shelled corn (UC Rp/kg) and break even point (BEP t); and discounted measures such as pay back period (PBP year), net present value (NPV Rp), benefit cost ratio (BCR -) and internal rate of return (IRR %).

The formulae for undiscounted measures were defined as:

$$UC = (FC + VC) / (X \times EC \times 1000) \dots\dots\dots(5)$$

$$BEP = \{FC / [SF - VC / (X \times EC)]\} \dots\dots\dots(6)$$

$$PBP = IC / (ANI) \dots\dots\dots(7)$$

The formulae for discounted measures (Suzuki, 1990) are defined thus:

$$NPV = \sum_{t=1}^{t=5} (Bt - Ct) / (1 + I)^t - IC \dots\dots\dots(8)$$

$$BRC = \sum_{t=1}^{t=5} (Bt / (1 + I)^t) / \{[Ct / (1 + I)^t] + IC\} \dots\dots\dots(9)$$

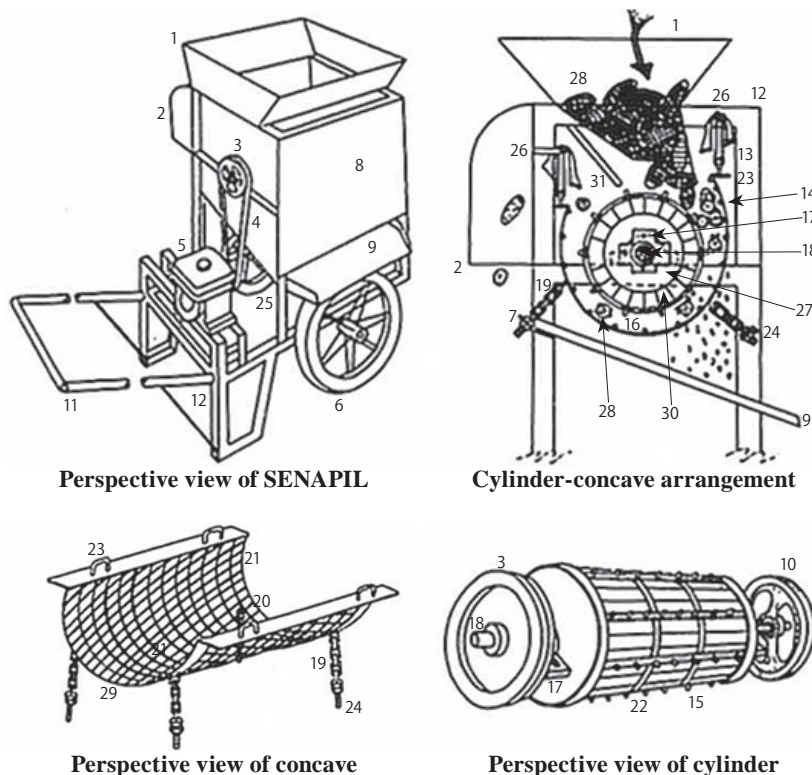
$$IRR = DFP + [PVP \times (DFN - DFP) / (PVP - PVN)] \dots\dots\dots(10)$$

To calculate the total added value, the following formulae were used:

$$DGP = (GD - 3.0) \times GPR \dots\dots\dots(11)$$

$$PUNC = [UNC / (100 - USC)] \times GP \dots\dots\dots(12)$$

Fig. 3 Schematic of the new prototype SENAPIL power sheller



- 1: Hopper, 2: Cob outlet, 3: Pulley diameter 230 mm, 4: V-belt B type, 5: Gasoline engine (7 hp), 6: Wheels, 7: Component for setting concave, 8: Front cover, 9: Grain outlet, 10: Flywheel, 11: Handle, 12: Machine frame, 13: Rubber spring, 14: Concave, 15: Shelling teeth, 16: Cylinder, 17: Lager, 18: As dis. 19 mm, 19. Chain, 20: Curved strip metal, 21: Curved iron rod, 23: Hook, 24. Bolt, 25. Pulley diameter 127 mm, 26: Hook, 27: Strip plate, 28: Husked cob, 29: Iron rod, 30: Wooden cylinder, 31: Cob resistor

$$DBRC = (1 - BRC) \times (1 - RSC) \times (1 + UNC) \times CCP / RSC \dots\dots(13)$$

The power sheller was considered feasible to be applied at the farm level if the value of NPV > 0, BRC > 1 and IRR > interest bank rate (24 %/year).

## Results and Discussion

### Comparative Analysis of the New Prototype and the Existing Sheller

From the three representative local shellers operated in the working area of KUD Nugroho, both SLM and KWT had a capacity of more than 2.0 t per hour (Table 1). However, KWT sheller was tested at 29 % w.b. grain moisture content and SLM sheller was tested at 24 % w.b. grain moisture content. It was reported that shelling capacity was significantly determined by grain moisture content (Chowdhury and Buchele, 1976; Nalbant, 1990; and Tastra et al., 1990). Therefore, for valid comparison of SENAPIL (Figure 3) performance with the SLM sheller (Figure 1), the same level of grain moisture content (24 % w.b.) was used.

The performance test of SENAPIL at the farm level showed that its effective capacity (4.82 t/h) was significantly higher than SLM's effective capacity (2.57 t/h) (Figure 4). In addition, the broken corncobs (96.63 % vs 35.18 %) and the grain mechanical

damage (12.33 % vs 5.04 %) were lower. The SENAPIL, with the vibrating concave system (Fig. 3), used input energy (7.0 hp gasoline engine) more efficiently than the SLM with the fixed concave system (Fig. 1). In addition, SENAPIL resulted in improved quality of the corncobs and shelled corn. However, the grain loss in terms of unshelled corn increased from 0.24 % to 1.62 %.

### Financial Analysis

It was assumed that average effective field capacity of SENAPIL was only 3.0 t per hour and SLM was 2.0 t per hour. Other data and assump-

tions used in the financial analysis of both corn shellers using equations 5-10 are presented in Table 2.

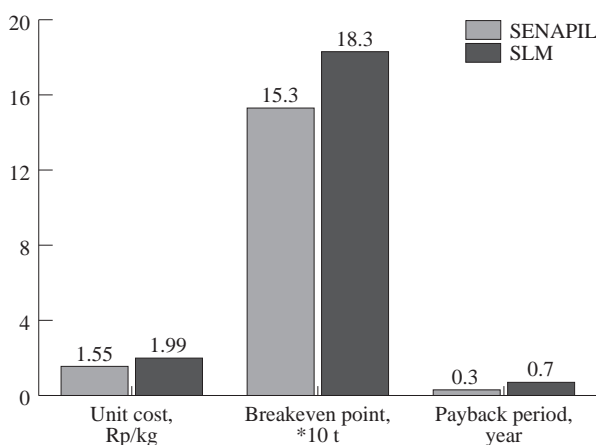
Fig. 5 shows a summary of the financial evaluation using undiscounted measures. With SENAPIL, the unit cost, break-even point and payback period can be reduced by about Rp 0.44/kg, 30 t shelled corn and 0.4 year, respectively. The two factors contributing to these reductions are the higher capacity and the lower investment cost of SENAPIL as compared to SLM sheller. The price of SENAPIL was Rp 1.4 million and SLM sheller was Rp 1.65 million. This analysis indicated that

**Table 2** Data and assumptions used in the financial analysis of the new power sheller (SENAPIL) and local sheller (SLM)

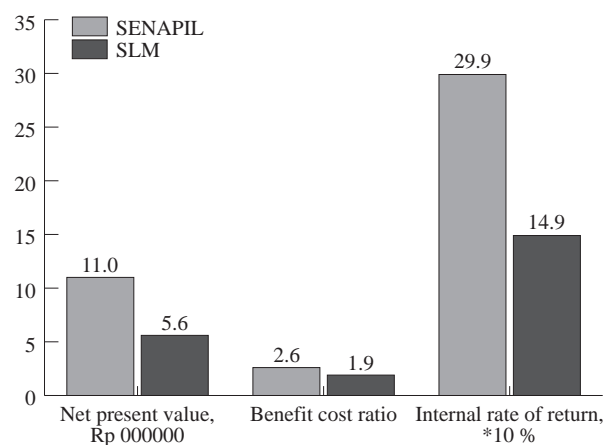
Description	Unit	SENAPIL	SLM
Days of operation	Days/year	80	80
Daily operation	Hours/day	5	5
Total hours operation	Hours/day	400	400
Interest rate	%/year	24	24
Repair and maintenance	% × IC	10	10
Expected economic life	year	5	5
Tax/insurance	% × IC	2	2
Wage rate for two operators	Rp/day	10,000	10,000
Shelling fee	Rp/kg	5	5
Effective capacity	kg/h	3,000	2,000
Fuel	l/h/hp	0.29	0.08
Oil	l/200 h	1.00	1.00
Oil price	Rp/liter	5,000	5,000
Fuel price	Rp/liter	550	350
Power source	hp	7.0	6.5
Investment cost* (IC)	Rp/unit	1,400,000	1,650,000

\*In 1992, 1 USD = Rp 3,000

**Fig. 5** Financial value of the new power sheller (SENAPIL) and the local sheller (SLM) with undiscounted method



**Fig. 6** Financial value of the new power sheller (SENAPIL) and the local sheller (SLM) with discounted method



SENAPIL is more economical than the SLM sheller.

Financial analysis with discounted measures showed that SENAPIL had higher net present value, benefit cost ratio and internal rate of return than the SLM sheller (Fig. 6). With 400 total working hours per year and shelling fee of Rp 5 per kg shelled corn, SENAPIL's net present value, benefit cost ratio and internal rate of return were Rp 11.0 million, 2.6 and 299 %, respectively. Therefore, using the SENAPIL in the working area of KUD Nugroho as well as at farm level in Indonesia was more feasible than using the SLM sheller.

#### Total Added Value of the New Prototype Power Sheller

The above economic analysis did not include the impact of the grain

damage, unshelled loss and the broken corn cobs to the total added value of using SENAPIL. Therefore, the reduction of the unit cost of Rp 0.44 per kg shelled corn (Fig. 5) must be corrected using equation 11 to 13.

By using formulae 11 to 13, the cumulative added value of the SLM sheller was Rp 0.32 per kg shelled corn and the total added value of SENAPIL sheller, including the reduction of the unit cost, was Rp 0.94 per kg shelled corn. In summary, although SENAPIL had higher unshelled loss than SLM sheller, the total added value was still higher than the total added value of SLM sheller.

Another added value of the new prototype (SENAPIL) was its simple construction and lower investment cost. With its simple construction, the prototype could be easily fab-

ricated and repaired at small workshops at the village level. With its low price (Rp 1.4 million per unit) it had good prospects for application at the farm level in Indonesia.

## Conclusions

1. The improved design power sheller (SENAPIL) has higher capacity (4.82 t/h), lower grain damage (5.04 %) and broken corncobs (35.18 %) than the existing local sheller (SLM).
2. With the vibrating concave system using rubber spring, the energy requirement for shelling process can be reduced as indicated by the fact that SENAPIL can be operated using gasoline engine 7.0 hp (5.25 hp diesel engine) while SLM requires a 6.5 hp diesel engine. Therefore, the investment cost SENAPIL (Rp 1.40 million/unit) is lower than SLM (Rp 1.65 million/unit).
3. Although SENAPIL had higher unshelled grain loss than SLM, SENAPIL's total added value (Rp 0.94/ kg shelled corn), B/C, NPV and IRR were still higher than SLM's added value (Rp 0.32/ kg shelled corn), B/C, NPV and IRR. Therefore, SENAPIL was found viable for application at the farm level in Indonesia.

#### Appendix 1 List of symbols and abbreviations used in equation 1-13

SC	Shelled corn (kg)
TPS	Time needed for shelling (s)
3.6	Conversion factor from kg/s to t/h
1000	Conversion factor from t to kg
HSG	Hand stripped grain (kg)
WGD	Weight of grain damage from 100 g sample (g)
WS	Weight of grain sample (100 g)
WBRC	Weight of broken corncobs (kg)
WOTC	Weight of total corncobs (kg)
FC	Fixed cost (Rp/year)
VC	Variable cost (Rp/year)
X	Working hours (hours/year)
SF	Shelling fee (Rp/kg)
IC	Initial cost (Rp)
ANI	Average annual net income (Rp/year)
Bt	Annual benefit (Rp/year)
Ct	Annual cost (Rp/year)
t	Expected economic life (years)
I	Interest rate (%/year)
DFP	Interest rate produced PVP (%)
DFN	Interest produced PVN (%)
PVP	Positive net present value (Rp)
PVN	Negative net present value (Rp)
DGP	Grain price reduction due to grain damage (Rp/kg)
3.0	Value of maximum grain damage standard (%)
GPR	Grain price reduction for each 1% increment of grain damage (Rp/kg)
PUNC	Price of unshelled corn loss (Rp/kg)
GP	Price of shelled corn (Rp/kg) (Rp 200/kg)
DBRC	Corncobs price reduction (Rp/kg)
RSC	Ratio of shelled corn (-) (RSC for SENAPIL = 0.82 and for SLM = 0.79)
CCP	Price of unbroken corncobs (Rp/kg) (Rp 25/kg)

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# Development of a Chopping Machine for Agricultural Residue (a Case Study on Grape Trashes)



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## Abstract

The feeding mechanism was modified throughout using two drums to make the feeding uniform, distribute the dynamic load and, consequently, reduce the vibrations and increase the machine stability. The cutting system was modified throughout with a 5 kW 1,500 rpm electric motor on the frame to obtain four different operating speeds by using two fabricated pulleys with different diameters. A moving frame with three wheels was used instead of the fixed frame to facilitate the conveying, adjusting and operation of the chopper. The field experiments were conducted at four cutting speeds of 0.75, 1.19, 1.33 and 1.81 m/s as well as four feeding speeds of 0.28, 0.45, 0.75 and 1.22 m/s. Two different shapes of cutting knives (straight edged and serrated edge) were used for cutting the grape residuals. The cutting efficiency, productivity, cutting length and energy consumed compared with energy of local cutting tools were studied. The obtained results can be summarized as follows:

Developing the feeding and cutting mechanisms of stationary Japanese chopper improved its performance by increasing its productivity and efficiency as well as decreasing cutting energy and chopping lengths. The maximum value of machine efficiency (93.16 %) and capacity (4.192 Mg/h) were accomplished with a feeding mechanism and cutterhead speeds of 1.22 and 1.88 m/s, respectively, using a serrated-edge. But, 0.28 m/s feeding mechanism speed and 1.88 m/s cutterhead speed gave the highest value of cutting efficiency (93.85 %).

The minimum value of chopping length was 1.0 cm at feeding mechanism speed of 0.28 and 0.75 m/s using serrated-edge cutting knives while the lowest value of energy consumed was 0.776 kW h/Mg at 1.22 m/s feeding mechanism speed and cutterhead speed of 0.75 m/s. The optimum performance of the developed chopper was obtained at feeding mechanism speed of 0.28 m/s and cutterhead speed of 1.88 m/s by using serrated-edge cutting knives.

## Introduction

The increase of quantity of many kinds of agricultural crop residues is considered one of the problems that face the farming and environmental life. Crop residues are the plant materials that remain after crops have been harvested. They include cotton stalk, maize and its shells, rice straw, bean straw, residues of vegetables and residues of horticulture productions where, the accumulation of these residues, if not treated in suitable ways, will have a bad effect on the environment. These effects might include economic losses, pollution, public health hazard, possibility of fire eruption and shelter for many pests.

The total cultivated area of fruit trees in Egypt is about 907,000 feddan (Ministry of Agriculture, 2003). Cutting fruit tree branches may be performed either individually during pruning or in bundles during chopping. Pruning is considered as an important practice in fruit production. However, pruning affects canopy division and cluster exposure, invigorates sheet growth

and improves light penetrations. The suitable number of buds, which are lifted after pruning would contribute to producing high yields and quality (Denesin, 1979; Janick, 1979 and Norman, 1985).

The Egyptian fruit growers currently use the manual pruning method with special clippers or portable saws. This practice requires a great deal of labor, equivalent to 3-8 % of production costs. Mechanical pruning devices are widely used in some foreign countries other than in Egypt. Over recent years, some researchers directed interest to the mechanical pruning devices such as mobile pruning plate forms and pneumatic or hydraulic pruners.

Glammetta and Zimb-alatti (1997), Lisa and Parena (1997), Branckoro and Marmugi (1997), Intrieri and Poni (1998) and Sperandio and Vetani (1998) found that mechanical pruning reduces the labor requirement and lowers the utilized time of the process. They added that the cut that is done by the pruning machines, causes a negligible damage compared with the

manual pruning. Moreover, if either mechanical or manual pruning was adopted, negligible difference in the fruit production was found.

FAO (1998) identified that, in Egypt, about 400,000 Mg fruit tree branches are pruned and burned annually. It is possible to utilize pruning residue in many industries such as baskets, cages, hencoops, breadboards, simple furniture and paper (Halwagi, 1982).

Leger et al. (1991), Rynk (1992) and Barington et al. (1997) stated that there is an interest in composting the agricultural residues. Also, it is economical to treat, stabilize and compost the pruning residues. Chopping of agricultural materials is commonly employed using rotary cutters and flail shredders.

Kanafojski and Karwowski (1976) indicated that in the cutting operation of the agricultural materials, the cutting process initiates when the cutting edge of the knife makes contact with the plant stem. Then during the continued motion of the knife through the plant stalk, the contact forces, stresses increase and

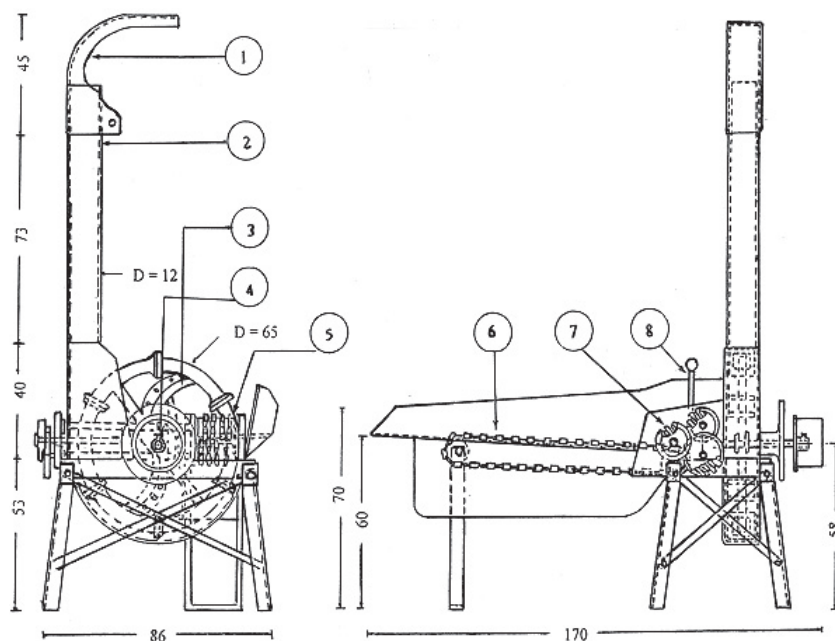
a stress pattern is built up inside the stem until failure conditions are reached.

Culpin (1981) indicated that two general types of cutterhead, known as flywheel type and cylinder type, have been employed on conventional field choppers. With either type, the mounting or shape of the knives is such that cutting occurs progressively from one end to the other to minimize peak torque requirements.

Hennen (1971) reported that the energy requirements at normal feed rates ranged from 1.0 to 1.5 kW h/Mg for a 13 mm theoretical cut with corn silage at 60 to 80 % moisture content and from 1.5 to 2.0 kW h/Mg for a 6 mm theoretical cut with mature corn silage at 40 to 60 % moisture content. Generally the total energy requirements per ton for a forage chopper decreased somewhat as the feed rate is increased, primarily because the power for blowing air and some minor power requirements are relatively independent of feed rate.

The objective of the present study was to develop, fabricate and evaluate technically and economically the feeding and cutting mechanisms of a chopping machine to be used for cutting the different crop residuals and pruning the fruit tree branches.

**Fig. 1** An elevation and side view of the stationary chopper



1: Material outlet, 2: Throat, 3: Cutterhead, 4: Impeller-blower, 5: Spring-loaded roller, 6: Feed mechanism, 7: Gear box, 8: Lever

## Materials and Methods

Field experiments were conducted during the agricultural season of

**Table 1** Technical specifications of chopping machine

Item	Specifications
Source of manufacture	Japan
Model	Yanmar SFC 1810
Overall length, cm	180
Overall width, cm	125
Overall height, cm	175
Net weight, kg	160
Width of roll, cm	18
Working capacity, kg/h	1000-4500
Power requirement, hp	2-6



2005 at the Rice Mechanization Center, Meet El-Dyba, Kafr El-Sheikh Governorate. The development process was carried out in the engineering workshop of the Rice Mechanization Center. A Japanese make forage chopper was modified in this study and was used for cutting grape branches. It consisted of the following main parts:

- a. Feeding mechanism with spring-loaded rolls to compress and hold the material for chopping.
- b. Cutterhead or chopping unit.
- c. A flywheel-type cutterhead with 2 impeller blades around the periphery that throw or impel the chopped material up the discharge pipe and into the wagon.

The cutting mechanism of the chopper was modified in this study by using two fabricated pulleys (driving and driven) with different diameters for operating the chopper with four different cutting speeds. A new feeding mechanism that consisted of two fabricated drums, was used to obtain uniform feeding of the residuals and attain the uniformity of the dynamic load on the engine. This increased the machine stability and the expected life of the machine. On the other side, a moving frame with three wheels was fabricated and used instead of the fixed frame to facilitate the conveying operation, which decreased the vibrations during the chopping operation. A 5 kW motor was fixed on the frame of the developed chopping machine.

The developed chopper is illustrated schematically in **Figure 1** and photographed in **Figure 2**. The technical specifications of the Japanese chopping machine are summarized in **Table 1**. Moreover, the cutting mechanism of the chopper before development is shown in **Figure 1**.

### Study Parameters

Field experiments were conducted to evaluate the chopping machine before and after development under the following parameters:-

1. Four levels of cutting speed (0.75, 1.19, 1.33 and 1.81 m/s).
2. Four ranges of feeding speed (0.28, 0.45, 0.75 and 1.22 m/s).
3. Two shapes of cutting knives are serrated and straight sided-edge shapes.

### Miscellaneous Equipment

- a. Digital vernier, (with an accuracy of about 0.01 millimeter).
- b. Mettler balance (sensitive to 0.01 g).
- c. Weighing balance with a maximum reading of 50 kg and accuracy of 0.5 kg.
- d. Stop watch

### Measurements of Machine Performance

#### 1. Cutting Efficiency:

The cutting efficiency was calculated according to following equation:

$$\eta_c = (W_{i,a} / W_b) \times 100 \%$$

where

$\eta_c$  = Cutting efficiency, %

$W_b$  = Mass of chopped materials on top sieve before segregation, g

$W_{i,a}$  = Mass of chopped materials after segregation.

#### 2. Capacity of Chopper:

The actual length of cut approximated the theoretical length only when stalks were fed in straight, as with row crops such as corn (Kepener et al., 1982). The theoretical capacity  $T_t$ , in Mg/hour, may be expressed by the relationship:

$$T_t = 6 \times 10^{-9} \rho \times A \times L \times N \times R, \text{ Mg/h}$$

where

$\rho$  = Density of material as it passed between the feed drums, kg/m<sup>3</sup>.

$A$  = Throat area, cm<sup>2</sup>.

$L$  = Theoretical length of cut, mm.

$N$  = Number of knives on cutterhead.

$R$  = Speed of cutterhead, rpm.

#### 3. Power Consumption:

An ammeter and voltmeter were used for measuring current strength and potential difference, respectively, before and during experiments. Readings of amperes (I) and volts (V) were taken before and during each treatment. The power consumption (W) was calculated from the values of amperes (I) and volts (V) by using the following formula (Lockwood and Dunstan, 1971).

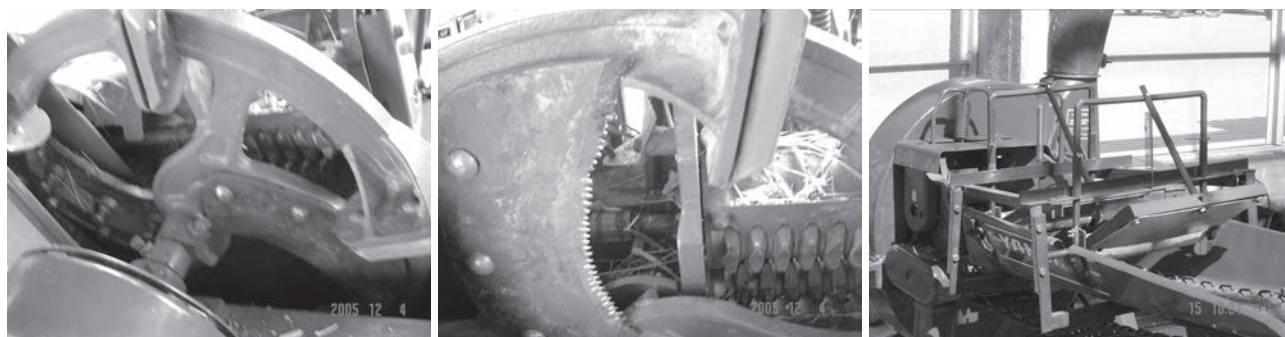
$$\text{Power consumption (W)} = \sqrt{3.1 V \cos\theta \eta}$$

where

$I$  = current strength, Amperes.

$V$  = potential difference, Volts.

**Fig. 2** The stationary chopping machine after modification



a. Straight-edge shape

b. Serrated-edge shape

c. Feeding

$\text{Cos}\theta$  = power factor, deci-mal (being equal 0.71).  
 $\eta$  = mechanical efficiency of motor assumed 90 %.

## Results and Discussion

### Efficiency of Stationary Chopper

The cutting length of final production was an important parameter for evaluation of the performance of the cutting process. The suitable cutting length used to produce the compost and animal organic (forage) was  $L_c \leq 50$  mm (36 and 52). Standard sieves with from 10 to 100 mm diameter holes were used to segregate a charge of final chopping production.

**Table 2** and **Figure 3** shows the efficiency of the developed chop-

ping machine as affected by feeding speed, cutterhead speed and cutting knife type. Data indicated that the increment in feeding mechanism speed from 0.28 to 1.22 m/s tended to increase the efficiency of the developed chopper from 75.86 to 86.63 % and 74.96 to 81.42 % for serrated and straight edge shapes, respectively, while the increase of cutterhead speed from 0.75 to 1.88 m/s tended to increase the efficiency of chopper from 77.71 to 86.6 % and from 73.76 to 82.16 % for serrated and straight edge shapes, respectively.

Generally, it was clear that the feeding mechanism speed of 1.22 m/s and cutterhead speed of 1.88 m/s gave the maximum value of chopper efficiency (93.16 %) with serrated edge shape compared with the other speeds under study. On the other

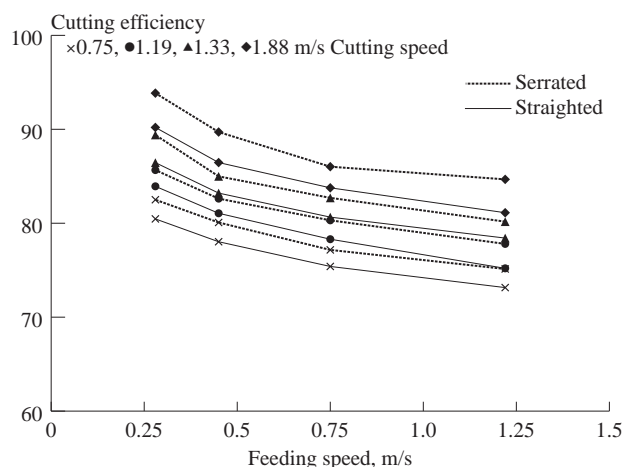
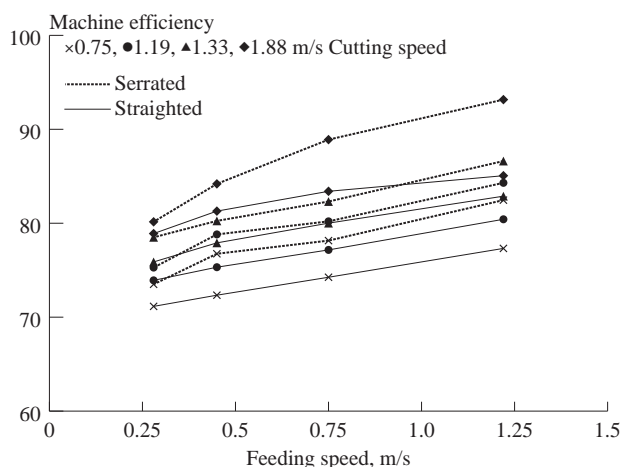
hand, the obtained values of chopper efficiency were 81.47 and 77.95 % for serrated and straight edge shape, respectively. The efficiency of the developed chopper increased by 4.52 % as a result of the use of the cutting knives of serrated edge shape as compared to the straight edge shape.

### Cutting Efficiency

The effect of cutting-edge sharpness, feeding mechanism speed and cutterhead speed on the cutting efficiency has been illustrated in **Table 2** and **Figure 3**. The cutting efficiency of the chopping processes increased by decreasing feeding mechanism speed and increasing the cutterhead speed for two types of cutting-edge shape. The cutting efficiency increased by 10.6 and 12.08

**Table 2, Fig. 3** Effect of cutting knife type, feeding and cutting mechanism speeds on cutting and machine efficiencies

Cutting speed, m/s	Average machine efficiencies					Average cutting efficiencies				
	Feeding speed, m/s					Feeding speed, m/s				
	0.28	0.45	0.75	1.22	Mean	0.28	0.45	0.75	1.22	Mean
<b>Serrated edge shape</b>										
0.75	73.50	76.75	78.15	82.46	77.71	82.50	80.08	77.16	75.13	78.72
1.19	75.28	78.81	80.20	84.30	79.65	85.66	82.62	80.31	77.80	81.60
1.33	78.50	80.25	82.31	86.62	81.67	89.40	84.99	82.70	80.17	84.31
1.88	80.15	84.19	88.90	93.16	86.60	93.85	89.71	86.02	84.67	88.56
Mean	75.86	80.00	82.39	86.63	81.47	87.85	84.35	81.55	79.44	83.30
<b>Straight edge shape</b>										
0.75	71.15	72.34	74.25	77.32	73.76	80.46	78.03	75.40	73.15	76.76
1.19	73.92	75.32	77.16	80.42	76.71	83.93	81.06	78.30	75.20	79.62
1.33	75.88	77.91	80.01	82.88	79.17	86.45	83.21	80.65	78.42	82.18
1.88	78.90	81.29	83.40	85.06	82.16	90.20	86.46	83.77	81.12	85.39
Mean	74.96	76.71	78.70	81.42	77.95	85.26	82.19	79.53	76.97	80.98



% as a result of decreasing feeding mechanism speed from 1.22 to 0.28 m/s for cutting knives of serrated and straight edge shape, respectively.

The increment percentage of cutting efficiency was 12.5 and 11.24 % when the cutterhead speed was increased from 0.75 to 1.88 m/s by using cutting knives of serrated and straight edged shape, respectively. The data also demonstrated that the cutting efficiencies were 83.3 and 80.98 % for serrated and straight-edge shapes, respectively. Generally, the cutting knives of serrated-edge shape gave the highest values of cutting efficiency compared with the straight-edge shape for all feeding mechanisms and cutterhead speeds.

Finally, it could be observed from the previous discussions that the feeding mechanism speed of 0.28 m/s, cutterhead speed of 1.88 m/s and cutting knives of serrated edge shape achieved the maximum values of cutting efficiency compared with the other ranges of parameters under study.

### Capacity of Stationary Chopper

Theoretical and actual capacity of the developed chopping machine as affected by the cutting knife type and feeding and cutterhead mechanism speeds are presented in **Table**

**3** and **Figure 4**. Increasing both feeding and cutting speeds tended to increase the actual capacities of the chopping machine with the two different types of cutting knife shape.

The actual capacity of the developed chopping machine increased by 28.6 % when the cutting speed increased from 0.75 to 1.88 m/s, while it decreased by 52.05 % as a result of decreasing the feeding speed from 1.22 to 0.28 m/s with the cutting knife of serrated edge shape. On the other hand, for all feeding and cutting speeds, the obtained values of actual capacities were higher for cutting knife of serrated edge shape compared with the straight edge shape.

Generally, the maximum values of actual capacities were 4.192 Mg/h at feeding speed of 1.22 m/s and cutterhead speed of 1.88 m/s by using cutting knife of serrated edge shape.

### Chopping Lengths

There was a significant effect of feeding mechanism speed, cutterhead speed and cutting knife type on the chopping lengths as shown in **Table 4** and **Figure 5**. The increase of cutterhead speed from 0.75 to 1.88 m/s tended to increase the chopping length by 24.1 and 60.5 % for serrated and straight-edge shapes.

The obtained mean values of

chopped lengths were 2.42 and 2.88 cm for cutting knives of serrated and straight-edge shapes, respectively. However, the serrated-edge shape gave the lowest values of chopping lengths for all different values of feeding and cutting speeds.

Finally, the feeding mechanism speed of 0.28 m/s, cutterhead speed of 0.75 m/s and cutting knives of serrated-edge shape recorded the minimum values of chopping lengths.

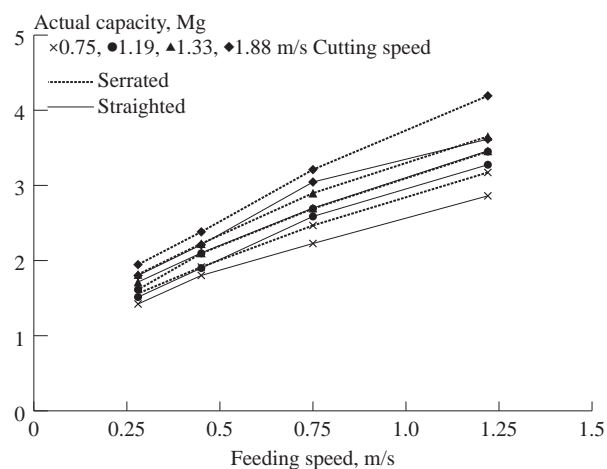
### Energy Consumption

The influence of feeding mechanism and cutterhead speeds as well as cutting knives type on the energy consumed has been shown in **Table 5** and **Figure 6**. There was a positive effect of feeding mechanism speed, type of cutting knives and cutterhead speed on the energy consumed during the cutting processes of grape branches.

The energy consumed decreased by 25.1 and 23.95 % when the feeding mechanism speed was increased from 0.28 to 1.22 m/s for cutting knives of serrated and straight-edge shape, respectively. However, the feeding mechanism speed of 1.22 m/s achieved the lowest values of energy consumed during the cutting processes of grape branches for all cutterhead speeds and types of cutting knives.

**Table 3, Fig. 4** Effect of cutting knife type, feeding and cutting mechanism speeds on actual capacity of chopping machine

Cutting speed, m/s	Average actual capacity of chopping machine, Mg/h				
	Feeding speed, m/s				Mean
	0.28	0.45	0.75	1.22	
<b>Serrated edge shape</b>					
0.75	1.562	1.914	2.467	3.172	2.279
1.19	1.613	2.096	2.691	3.450	2.462
1.33	1.815	2.225	2.897	3.651	2.647
1.88	1.946	2.382	3.210	4.192	2.932
Mean	1.734	2.154	2.816	3.616	2.580
<b>Straight edge shape</b>					
0.75	1.422	1.802	2.227	2.861	2.078
1.19	1.514	1.900	2.587	3.275	2.319
1.33	1.714	2.102	2.698	3.460	2.493
1.88	1.801	2.210	3.045	3.616	2.668
Mean	1.613	2.003	2.639	3.303	2.389



The data also indicated that increasing the cutterhead speed from 0.75 to 1.88 m/s caused an increase in the energy consumed for all feeding speeds and types of cutting knives. The energy consumed increased by 54.8 and 51.4 % when the cutterhead speed was increased from 0.75 to 1.88 m/s for serrated and straight-edge shapes, respectively. Generally, the cutterhead speed of 0.75 m/s recorded the minimum values of energy consumed for all feeding mechanism speeds and cutting knives.

The obtained mean values of energy consumed were 1.215 and 1.392 kW h/Mg for serrated and straight-edge shapes, respectively. Finally, it can be concluded from the previous

results that the feeding speed of 1.22 m/s cutterhead speed of 0.75 and serrated-edge shape recorded the minimum values of unit energy.

## Conclusions

In this study, the cutting mechanism of the Japanese forage chopper was developed through pruning the grape tree branches. Throughout this study the following conclusions were drawn:

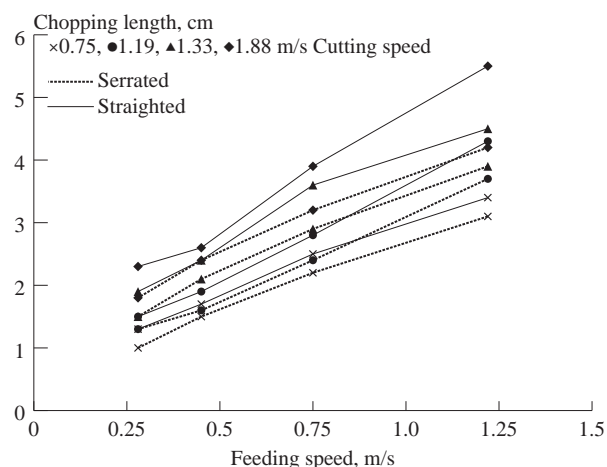
1. Development of a feeding mechanism and system for a Japanese stationary chopper tended to decrease the vibrations and cutting energy as well as increase the productivity

efficiency and expected life of chopper compared with the chopper before development.

2. The feeding mechanism and cutting speeds of 1.22 and 1.88 m/s accomplished the highest value of machine efficiency (93.16 %) by using the serrated-edge shape. The maximum cutting efficiency was attained at a feeding mechanism speed of 0.28 m/s and cutterhead speed of 1.88 m/s using cutting knives of serrated-edge shape.
3. The maximum value of chopper capacity was 4.192 Mg/h at feeding mechanism speed of 1.22 m/s, cutterhead speed of 1.88 m/s and cutting knife of serrated-edge shape.

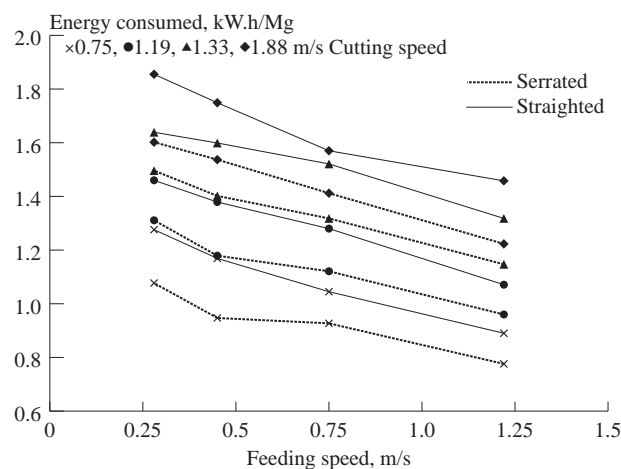
**Table 4, Fig. 5** Effect of cutting knife type, feeding and cutting mechanism speeds on the chopping length

Cutting speed, m/s	Average chopping length, cm				
	Feeding speed, m/s				Mean
	0.28	0.45	0.75	1.22	
<b>Serrated edge shape</b>					
0.75	1.0	1.5	2.2	3.1	1.95
1.19	1.3	1.6	2.4	3.7	2.25
1.33	1.5	2.1	2.9	3.9	2.60
1.88	1.8	2.4	3.2	4.2	2.90
Mean	1.4	1.90	2.68	3.72	2.42
<b>Straight edge shape</b>					
0.75	1.3	1.7	2.5	3.4	2.23
1.19	1.5	1.9	2.8	4.3	2.62
1.33	1.9	2.4	3.6	4.5	3.10
1.88	2.3	2.6	3.9	5.5	3.58
Mean	1.75	2.15	3.20	4.43	2.88



**Table 5, Fig. 6** Effect of cutting knife type, feeding and cutting mechanism speeds on the energy consumed

Cutting speed, m/s	Average energy consumed, kW.h/Mg				
	Feeding speed, m/s				Mean
	0.28	0.45	0.75	1.22	
<b>Serrated edge shape</b>					
0.75	1.077	0.947	0.927	0.776	0.932
1.19	1.311	1.179	1.121	0.960	1.143
1.33	1.496	1.402	1.318	1.147	1.341
1.88	1.602	1.537	1.412	1.223	1.443
Mean	1.371	1.266	1.195	1.027	1.215
<b>Straight edge shape</b>					
0.75	1.276	1.169	1.045	0.890	1.095
1.19	1.460	1.379	1.280	1.071	1.297
1.33	1.639	1.599	1.521	1.318	1.519
1.88	1.855	1.749	1.570	1.458	1.658
Mean	1.557	1.474	1.354	1.184	1.392



4. The results demonstrated that the minimum value of chopping length was 1.0 cm using cutting knife of serrated-edge shape at feeding mechanism and cutterhead speeds of 0.28 and 0.75 m/s respectively.
5. From the energy point of view, it can be concluded that the lowest value of unit energy, 0.776 kW h/Mg, was obtained at 1.22 m/s feeding mechanism speed and 0.75 m/s cutterhead speed using chopping knife of serrated-edge shape.
6. The data also indicated that the cutting tools (knives) of serrated-edge shape are considered better than the cutting tools of straight-edge shape because the first one achieved the maximum values of productivity, machine and chopping efficiency as well as the minimum values of chopping energy and lengths.
7. It is recommended that the operators of pruning and chopping machines for fruit tree branches operate the developed Japanese chopper at a feeding mechanism speed of 0.28 m/s and cutterhead speed of 1.88 m/s by using cutting tools of serrated sided-edge shape to obtain the optimum performance.

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# Establishment and Performance of Indegenous Small Scale Rice Processing Plant in Nigeria

by  
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## Abstract

A small scale Rice Processing Plant with 3 tons per day capacity was established for the Burma Rice farm in Bayelsa State of Nigeria by the National Cereals Research Institute, Badeggi. All the machines were fabricated in the Institute while the Nigerian Agip Oil Company Ltd, Port-Harcourt provided the funds for the entire project, including the factory building and other farm structures. The factory was divided into five main sections; threshing and winnowing area, parboiling bay, drying and tempering, milling and quality control/bagging unit. The machines installed in the factory were; one rice thresher, one winnower, three rice parboilers, one rotary steam dryer, four milling machines and one pneu-

matic cleaner. The overall milling recovery of the plant was about 70 %. The performances of the various components have been highlighted.

## Introduction

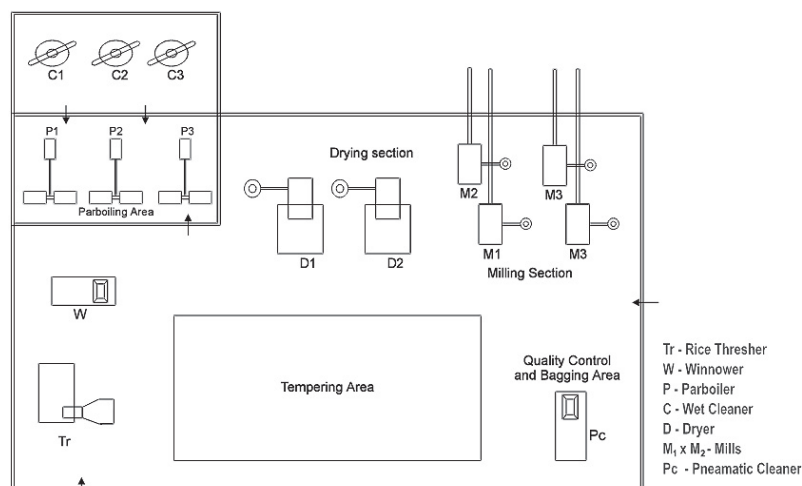
Rice (*Oryza sativa L*); believed to have originated from ancient China is one of the most important staple food crops for more than half of the world's population (Bandyopadhyay and Roy, 1992). The rice seed contains about 66.4 % starch, 12 % iron and 26.3 % amylose (Resurrection et al., 1979) while its energy and protein contents are 3.75 % and 7.5 % respectively (IRRI, 1993).

The potential of Nigeria in rice production in terms of availability of land, market, human resources

and weather is so enormous but the actual rice production level of the nation is so low that the country imports rice worth 600-700 million dollars annually (The Guardian 2002). Also, in spite of the huge rice requirement of the country, the per-capita rice production of 21 kg is very low compared to other West African sub-region countries such as Guinea, Gambia and Sierra-Leone which had 135 kg, 110 kg and 108 kg, respectively (NCRI, 1997).

In order for the nation to be self sufficient in local rice production, Individuals, corporate organization and the state and federal governments need to utilize the available land potential of 4.6-4.9 million hectares (Kehinde, 1997 and Indachaba, 1985) available in the country. Recently, the federal government of Nigeria has just inaugurated a committee to come up with a blue print to increase rice production in Nigeria by the year 2004. However, as part of the effort by the Bayelsa state government of Nigeria to encourage rice production, the Burma Rice Farm was established through a collaborative effort by the Nigeria Agip Oil Company Limited, Port Harcourt and the National Cereals Research Institute, Badeggi. The aim of the project was to establish a 3 tons per day Rice Processing Plant to augment the existing rice production capability of the state, provide source of avenue for local rice farmers to process their crop, provide ru-

**Fig. 1** Layout of human rice processing factory



ral employment for the unemployed youths and generally contribute to rural development in the state.

The Nigerian Agip Oil Company Limited, Port Harcourt, which undertakes oil prospecting activities in Bayelsa state provided the funds for the whole project while the National Cereals Research Institute, Badeggi provided the processing equipment.

The paper highlights the components of the Burma Rice Processing Factory and gives an overview of the general performance of the factory.

## Factory Layout

The Rice processing plant layout at the Burma Rice farm has the following five main sections as shown in Fig. 1.

**1. Threshing and Winnowing areas:** This is the area where harvested rice from the field are threshed and cleaned. The harvested rice tied in bundles is loaded into trucks

on the farm road by labours and transported to the threshing area of the factory. The threshed rice is collected and cleaned with the reciprocatory winnower before weighing and bagging. The straw, which is the major by-product of the threshed rice, is spread on the field in order to improve the fertility of the soil.

**2. Parboiling Bay:** The cleaned rice is treated hydrothermally in this section. Thus, this area basically houses the parboilers and the wet cleaners. Ample space is provided to accommodate bags of rice and allow movement of people while working. A pipe network that conveys water from the overhead water storage tank into the boilers and also serves the wet cleaners is accommodated in this area.

**3. Drying and Tempering Section:** The dryer units are installed in this section. The two units of the dryer, rotary drying chamber and brick wall insulated boiler sections are conveniently accommodated. A tempering area is also provided in this area to allow for equilibration of moisture between and within rice kernels after parboiling and the first

and second pass drying.

**4. Milling Section:** Tempered rice is milled in this area before taken for final cleaning. A husk collection point is provided outside the milling area where they are conveyed and deposited with the aid of 3 inch PVC pipes and cyclones.

**5. Quality Control and Bagging Area:** This is the finishing section where milled rice is cleaned by the pneumatic cleaner before weighing and bagging in varying sizes of sachets and bags.

## Production Process

The production process of the small scale processing plant at Burma is explained in Fig.2.

Bundles of harvested rice from the field are left for about 2-4 days depending on the wetness and maturity of the seeds to enable them to lose enough moisture that accompanies them from the field. They are then threshed by throwing in a handful (3-5 kg) of the panicle into the machine at intervals of about 30-60 seconds depending on the load. The

Fig. 2 Flow chart of the Burma rice processing factory

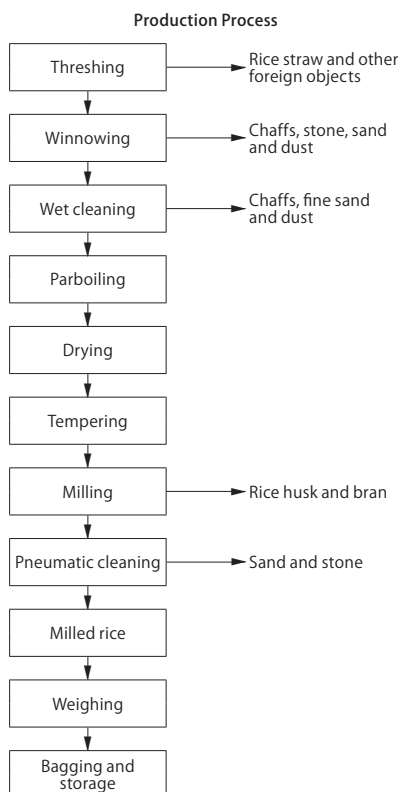


Table 1 Threshing data

Quantity of threshed rice per hr ( $T_r$ ), kg	Quantity of threshed rice per day ( $T_{rd}$ ), kg	Quantity of un-threshed rice ( $T_u$ ), kg	Threshing efficiency, $\eta_{cy}$ , %
400	3,200	0.1	99.98
370	2,960	0.5	99.99
405	3,240	0.2	99.95
420	3,360	0.08	99.98
415	3,320	0.1	99.98

Table 2 Winnowing data

Rice variety	$M_i$ , kg	$M_f$ , kg	t, min	$M_s$ , kg	$M_m$ , kg	$M_{op}$	$\eta_{cy}$ , %	$\eta_{rcy}$ , %	$C_{mo}$ , kg/day
Faro 52	1,000	992.0	90	7.0	0.5	0.5	93.33	99.95	5,290.6
Faro 35	1,000	991.7	83	7.2	0.7	0.4	91.4	99.97	5,735.13
DA 29	1,000	993.7	75	5.4	0.6	0.3	90.0	99.97	5,746.7
Faro 43	1,000	990.3	92	8.5	0.75	0.45	91.89	99.98	5,166.78
Faro 29	1,000	995.0	80	4.0	0.6	0.4	86.96	99.94	5,970.0
Faro 24	1,000	899.0	76	9.2	0.62	0.38	93.69	99.94	5,677.89

$M_i$ : Initial mass of paddy,  $M_f$ : Final mass of paddy after winnowing, t: Time spent on winnowing,  $M_s$ : Mass of foreign separated materials using machine,  $M_m$ : Mass of separated materials using manual method,  $M_{op}$ : Mass of lost paddy using machine,  $\eta_{cy}$ : Cleaning efficiency of machine,  $\eta_{rcy}$ : Seed retention efficiency,  $C_{mo}$ : Output capacity of machine

threshed rice which is collected with two fabricated rectangular containers of 70 × 85 cm are poured onto a tarpaulin. They are then introduced into the winnower with the aid of a basin. The chaff, stones, sand and dust are separated by different screens in a reciprocatory assembly while the cleaned seeds are collected through a different spout. The winnowed seeds are further cleaned to remove the dust that adheres firmly to the husks and minute impurities/chaffs. About 30-40 kg of paddy are cleaned per cycle of 10 minutes and discharged into the parboiling tanks where they are soaked in water at a temperature of 70 °C from the boiler for a period of 8-12 hours. The water is then drained through valves and is passed on to the rice for 45-60 minutes interval. The parboiled rice (which is indicated by cracking of over 98 % the steamed rice) is discharged at about 45 % moisture content and tempered to 35-40 % moisture content within 1-2 hours before drying.

They are dried with the rotary steam dryer for about 3 hours before discharging at 20-22 % moisture content and tempered again for about 3-6 hours. This first pass-tem-

pered rice is loaded into the dryer for second pass drying for about 2 hours. They are discharged at about 16 % moisture content and tempered further in the tempering area for 18-24 hours before milling.

The milled rice is finally cleaned and graded with the reciprocatory pneumatic cleaner before bagging and storage.

## Plant's Components and Performance Assessment

The following machines and equipment were installed in the Burma Rice farm:

### Rice Thresher

The thresher was made of a trap-ezoidal hopper, threshing assembly, straw outlet, frame and power unit as shown in **Fig. 3**. The threshing assembly was comprised of the threshing drum that rotated within a concave made of steel rods. The drum was mainly composed of studs which were bolted to flat bars that were arranged longitudinally at a distance of 10 cm from one another. Power was supplied to the

cylindrical threshing drum by a 10 hp air cooled diesel engine.

Rice weighing about 5 kg was fed into the thresher through the hopper. The impact force of the drum (rotating at an average speed of 500 rpm) on the rice panicles dislodged the seed from the straw. The rice straw and chaff were discharged through the straw outlet due to the spiral arrangement of the bars on the rotating drum while the threshed rice seed and some chaff were collected by gravity through the concave into the collector. The few unthreshed rice were dislodged from the panicles manually. The total threshed rice after winnowing and the unthreshed ones dislodged manually were weighed and recorded as shown in **Table 1**. The efficiency of the thresher was computed to range from 99.5-99.99 % as given in equation 1.

$$\text{Threshing efficiency } \eta_{cy} = (T_r / T_r \times T_u) \times 100 \% \dots\dots\dots(1)$$

where

$T_r$  = Quantity of threshed rice (kg)

$T_u$  = Quantity of unthreshed rice (kg)

$\eta_{icy}$  = Efficiency of Thresher (%)

### Reciprocatory Winnower

As shown in **Fig. 4**, the Reciprocatory Winnower was composed of a hopper, reciprocatory sieve assembly, chaff outlet, fine impurities, spout and seed outlet. The sieve assembly was essentially made of three metal screens of 2.5 mm, 5 mrn and 10 mrn diameter holes. They were arranged at an inclination angle of 45° to the horizontal plane. A reciprocatory cam mechanism, which was attached to this assembly obtained power from a 5 hp single phase electric motor through pulleys and belts.

A centrifugal blower which obtained power from the pulley of the reciprocatory assembly was incorporated at the rear end of the reciprocatory system to expel chaff and other lighter impurities.

About 1,000 kg of threshed rice

**Table 3** Wet cleaning data

Rice variety	$M_p$ , kg	$t_{a1}$ , mins	$t_{i1}$ , mins	$t_{a2}$ , mins	$t_{i2}$ , mins	$t_d$ , mins	$t_r$ , mins	$t_a$ , mins	$C_a$ , kg/day
Faro 52	25	2.0	1.0	2.0	2.0	2.0	9.0	10.33	1,161.67
	25	2.0	3.0	2.0	3.0	2.0	12.0		
	25	2.0	2.0	2.0	2.0	2.0	10.0		
Faro 35	35	2.0	3.0	2.0	3.0	2.0	12.0	11.00	1,527.27
	35	2.0	2.0	2.0	2.0	2.0	10.0		
	35	2.0	3.0	2.0	2.0	2.0	11.0		
Faro 43	45	2.0	2.0	2.0	3.0	3.5	12.5	12.83	1,683.55
	45	2.0	3.0	2.0	3.0	3.0	13.0		
	45	2.0	3.0	2.0	3.0	3.0	13.0		
Faro 29	60	2.0	3.0	2.0	3.0	4.5	14.5	13.83	2,082.43
	60	2.0	2.0	2.0	3.0	4.0	13.0		
	60	2.0	3.0	2.0	3.0	4.0	14.0		
Faro 24	75	2.0	4.0	2.0	4.0	6.0	18.0	17.17	2,096.68
	75	2.0	3.0	2.0	4.0	7.0	18.0		
	75	2.0	2.0	2.0	4.0	5.5	15.5		

$M_p$ : Mass of paddy,  $t_{a1}$ : Time spent on first agitation,  $t_{i1}$ : Time taken for removal of lighter impurities,  $t_{a2}$ : Time spend on second agitation,  $t_{i2}$ : Time spend on removal of more lighter impurities,  $t_d$ : Cleaned grains discharging time,  $t_r$ : Total time per cycle of cleaning,  $t_a$ : Average time per cycle of cleaning,  $C_a$ : Average capacity of cleaner



per batch were fed into the machine through the hopper with the aid of a shutter. The reciprocatory action of the screens enabled cleaned seed to pass through the upper and middle screens and be discharged through the seed outlet while the straw, chaff and stones were trapped and discharged at the front of the machine due to the combined effect of the screen movement and the centrifugal air blower. The fine impurities (sand) and rice seed were trapped below the upper and middle screens and discharged through different outlets. The winnowed rice was weighed and further cleaned manually. As shown in **Table 2**, the cleaning efficiency and capacity of the machine ranges between 87.0-94.0 % and 5,291.0-5678.0 kg/day, respectively, using equation (2) and (3).

$$M_s = M_i - M_f \dots\dots\dots(2)$$

$$\eta_{cy} = [M_s / (M_s + M_m)] \times 100 \% \dots\dots\dots(3)$$

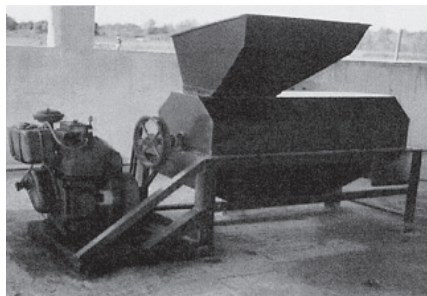
$$\eta_{ry} = [M_{cp} / (M_{cp} + M_{lp})] \times 100 \% \dots\dots\dots(4)$$

$$C_{mo} = [M_f / t \text{ (mins)}] \times 60 \text{ mins} \times 8 \text{ hr/day} \dots\dots\dots(5)$$

where

- $M_i$  = Initial mass of paddy (kg),
- $M_f$  = Final mass of paddy (kg),
- $T$  = Time spent on machine winnowing (min.),
- $M_s$  = Mass of separated foreign materials (kg),
- $M_m$  = Mass of manually separated materials (kg),
- $M_f$  = Final mass of paddy (kg).
- $M_{lp}$  = Mass of lost paddy (kg).
- $\eta_{cy}$  = Cleaning efficiency (%)
- $\eta_{ry}$  = Seed retention efficiency (%)
- $C_{mo}$  = Output capacity of machine

**Fig. 3** Rice thresher



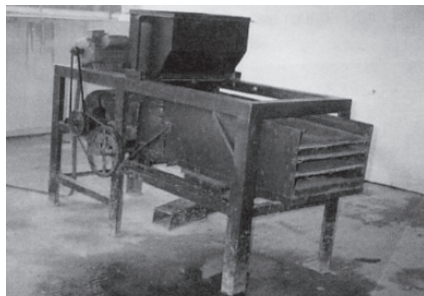
(kg/day)

**Wet Cleaners**

Three wet cleaners were provided. These were cylindrical vessels having removable stirring assemblies and drain valves as given in **Fig. 5**. Cleaning was done by introducing winnowed rice of different mass into the vessel containing water. The stirrer was then turned vigorously at an average speed of 30 rpm for 2 minutes. The difference in specific gravity of the rice seed, chaff and other impurities enabled them to be separated from one another. The lighter impurities that float on the water were removed with a plastic mesh and the stirrer was turned on again for one more minute for lighter materials to be removed before discharging the filled grains.

The time taken for removal of the impurities were also recorded. This operational procedure was repeated with subsequent batches for about 5 to 7 times before draining the water and washing off the sand that deposited on the base of the vessel. The time taken for each operation was recorded as shown in **Table 3**. The capacity of the cleaner was calculated with the aid of equation (6). Although the capacity of the cleaner increased with increasing load per batch, the 45 kg load per batch, which resulted in an average cleaning capacity of 1,167.57 kg per 8 hr working day was found to be the optimum loading capacity. This was because it yielded the desired capacity of 1,000 kg per day and also was easier to operate compared to the 60

**Fig. 4** Reciprocatory winnower



kg and 75 kg load per batch.

$$C_{aw} = (M_p / T_p) \times 60 \text{ mins} \times 8 \text{ hr/day} \dots\dots\dots(6)$$

where

$C_{aw}$  = Average capacity of wet cleaner (kg/day)

$T_a$  = Average cleaning time per batch (mins)

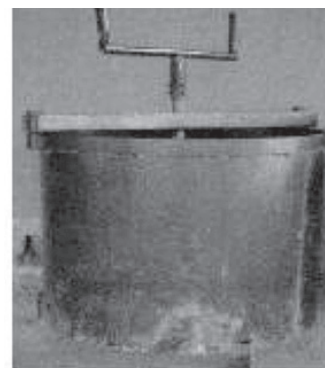
$M_p$  = Mass of paddy

**Rice Parboilers**

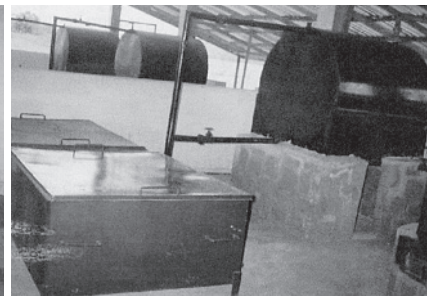
Three rice parboilers were fabricated for the farm. The equipment had two main sections; boiler and parboiling units that were interconnected by a network of 50 mm diameter pipes. The boiler, which was made of 2.5 mm mild steel sheet had a pressure relief system, drain valve, cold water inlet and hot water and steam outlets. It was placed over a furnace made of brick. The steaming unit was rectangular in shape and made of 2.5 mm galvanized sheet. A cover was provided to prevent loss of steam while a false bottom was placed 15 cm away from the base of the tank (**Fig. 6**).

Rice (1,000 Kg) from the wet

**Fig. 5** Wet cleaners



**Fig. 6** Rice parboilers



cleaner was introduced into the soaking/steaming tank containing water released from the boiler at 70 °C. The water was drained after 8 hours and steam was passed on to the tank from the boiler and left until the husks cracks. They were then unloaded and tempered for about 1-2 hours before feeding into the rotary steam dryer. The duration taken for the rice to crack during the steaming operation, quantity of white belly rice and colour difference of the rice were recorded as shown in **Table 4**.

The parboiling efficiency of the equipment was approximately 100 % as percent white belly was either

very negligible or totally absent in all the rice varieties as computed in equation (7) and (8). The colour difference for faro 52 was lower while that of DA 29 was highest.

$$W_b = (M_{wb} / M_r) \times 100 \% \dots\dots\dots(7)$$

$$\eta_{pcy} = [(M_r - M_{wb}) / M_r] \times 100 \% \dots\dots\dots(8)$$

where

$W_b$  = Percent white belly (%)

$M_{wb}$  = Mass of white belly rice (kg)

$M_r$  = Total Mass of parboiled rice (kg)

$\eta_{pcy}$  = Parboiling efficiency of machine (%)

**Table 4** Rice parboiling data

Rice variety	$M_r$ , kg	$t_d$ , mins	$t_s$ , mins	$M_{wb}$ , kg	$W_v$	E	c, %
Faro 52	1,000	480	60	0	0	6.3	100
	1,000	480	60	0	0	6.1	100
	1,000	480	60	0	0	6.5	100
DA 29	1,000	480	75	0	0	9.3	100
	1,000	480	75	0	0	9.7	100
	1,000	480	75	0	0	8.4	100
ROK 5	1,000	480	60	0	0	7.5	100
	1,000	480	60	0	0	7.0	100
	1,000	480	60	0	0	6.8	100
CK 77-3-2-2	1,000	480	90	0	0	8.2	100
	1,000	480	90	0	0	7.9	100
	1,000	480	90	0	0	8.5	100

$M_r$ : Mass of rice,  $t_d$ : Soaking duration,  $t_s$ : Steaming duration,  $M_{wb}$ : Mass of white belly rice,  $W_v$ : Percent white belly, E: Colour difference, c: Parboiling efficiency

**Table 5** Drying data for rotary steam dryer

Rice variety	M, kg	$t_i$ , mins	$t_r$ , mins	$t_t$ , mins	$t_{ia}$ , mins	$t_{ia}$ , mins	$t_{fa}$ , mins
Faro 52	600	150	120	12	24		
	600	150	120	12	24	150	123.33
	600	120	130	12	24		
DA 29	600	180	140	12	24		
	600	190	135	12	24	190	131.67
	600	200	120	12	24		
ROK 5	600	150	140	12	24		
	600	150	120	12	24	160	131.67
	600	180	135	12	24		
CK 77-3-2-2	600	200	150	12	24		
	600	150	180	12	24	176.67	160
	600	210	150	12	24		

M: Mass of parboiled paddy,  $t_i$ : Initial drying time from 30 % m.c to 18 % m.c,  $t_r$ : Final drying time from 16 % m.c to 13.5 % m.c,  $t_t$ : Tempering duration between initial and final drying,  $t_{ia}$ : Tempering duration after final drying,  $t_{ia}$ : Initial average drying time,  $t_{fa}$ : Final average drying time

### Rotary Steam Dryer

This machine dried about 1.5 tons of parboiled rice per day. Two of these were provided in the factory. It was composed of the boiler placed over a bricks furnace and rotary drying unit, which were interconnected with 4 mm diameter pipe. The rotary drying unit was a double wall insulated vessel with a jacket between the two walls for steam circulation. It also had provision for condensation outlet and sets of screens that permitted exit of moist air from the drying rice. Power of rotation of the drum was obtained from a 20 hp electric motor while firewood or gas was used as a source of heat.

About 600 kg of parboiled and tempered rice were fed into the rotary drying unit through a detachable hopper. The dryer was put on while water was heated in the boiler to raise steam. The drum with the content was allowed to rotate at 5 revolutions per minute until the moisture content was reduced from about 40 % to 20 % before they were discharged. The rice was then left to temper for about 3 hours and re-introduced for the second pass drying for the moisture to be reduced further to 16 %. The content was finally released and tempered for another 18-24 hours before milling. The drying time for the first and second pass for each variety were noted.

As shown in **Table 5**, the average drying time varied from 150-190 minutes during the first pass and 123.33-160 minutes for the second pass.

### Rice Mills

Two pair of rice mills were installed in the factory. Each pair dehusked and polisheed parboiled dried rice. They were made of a frustrurn hopper, milling chamber, husk aspiration unit, milled rice, spout and power unit (**Fig. 7**).

The milling chamber, which rotated at about 650-750 rpm was comprised of a milling cylinder that

was enclosed within a half cylindrical casing and sets of screen at the upper and lower sides. Power to the milling and husk aspiration units were supplied by a 15 hp electric motor through pulleys and belts.

The dried rice was put into the machine through the hopper while the shutter was closed. The machine was then put on for 2-3 minutes before releasing the shutter slowly for the rice to be dehusked in the first mill of each set. Proper dehusking was ensured by adjusting the pressure device at the spout. The dehusked rice was then polished in the second set of rice mills using the same procedure. The milling recovery, dehusking efficiency and whole grain efficiency were determined using equation (9) and (10).

The dehusking efficiency of the rice mill was found to be about 100 % while the whole grain efficiency varied between 99.74 to 99.97 % as the percent broken grains were very minimal as shown in **Table 6**.

$$M_r = (M_m / M_d) \times 100 \% \dots\dots\dots(7)$$

$$d_{cy} = (M_u / M_m) \times 100 \% \dots\dots\dots(8)$$

$$W_{cy} = [M_w / (M_w + M_b)] \times 100 \% \dots\dots\dots(9)$$

where

$M_r$  = Milling recovery of rice (%)

$M_m$  = Mass of milled rice (kg)

$M_d$  = Mass parboiled dried rice

(kg)

$M_w$  = Mass of whole grain (kg)

$M_b$  = Mass of broken grains (kg)

### Pneumatic Cleaner

This machine cleaned milled rice to ensure that fine sand and bran that still accompanied the rice after the initial winnowing and wet cleaning operations were removed. The machine was similar to the winnower except that the reciprocatory assembly of the pneumatic cleaner was suspended with four flat spring iron bars while the one in the pneumatic cleaner was suspended with a spiral spring iron. Three sets of screens inclined at different angles of 150, 250 and 450 were incorporated in the reciprocatory unit. Also, spouts for collection of cleaned rice, fine sand and dusts and broken grains were provided within the same assembly. Power to the reciprocatory and blower units was provided by a 5 hp single phase electric motor.

Milled rice was introduced into the reciprocatory screen assembly through the hopper after switching on the machine. The shutter in the hopper was released to regulate the flow rate of the material into the screen assembly. The reciprocatory action of this unit, which moves at 1.2 m/sec resulted in separation of

the fine sand, broken grains and whole grains, which were collected through different spouts. The rice bran and other lighter impurities were separated by a forced air stream at a velocity of about 7.5 m/sec generated by the blower.

## Production Input and Raw Materials

The major raw material in the plant was rice. Other inputs include water, firewood, diesel, engine and gear oils. Water was used in wet cleaning, parboiling of rice and heating medium in the rotary driers. Diesel engine and gear oils were used as fuel for the 150 KVA electricity generating plant. They were also used as a fuel source for the engine of the rice thresher and lubricant for the gear boxes of the rotary driers.

### Sources of Raw Materials

Rice, the major raw material, was obtained from the Burma Rice farm, which was located around the factory. Currently about 20 hectares of the farm have been cultivated. Since it would be expanded to 50 hectares within three years, enough raw materials were expected to be obtained from the farm. An out grower scheme proposed by the Bayelsa State government was expected to ensure the availability of raw materials in the factory.

### Products/By-Products and Their Utilization

The main product was milled rice while rice straw, husk and bran were the by-products generated from the factory.

The milled rice was packaged in 2 kg polythene sachets and 10 kg, 25 kg and 50 kg transparent nylon bags for sale. The rice bran was sold to fish and poultry farmers while the rice straw was spread and worked into the field as organic manure to supplement the soil nutrient.

**Table 6** Milling data

Rice variety	$M_d$ , kg	$M_m$ , kg	$M_w$ , kg	$M_b$ , kg	$M_u$ , kg	$m_a$ , kg	$M_{aw}$ , kg	$w_{cy}$ , %	$d_{cy}$ , %	$M_r$
Faro 52	1,000.0	696.8	696.4	0.3	-	68.68	99.94	100.0		
	1,000.0	711.3	711.1	0.2	-	71.13	99.97	100.0	704.53	70.43
	1,000.0	705.5	705.2	0.2	-	70.55	99.96	100.0		
DA 29	1,000.0	690.1	689.1	0.9	-	69.01	99.86	100.0		
	1,000.0	703.1	702.3	0.7	-	70.31	99.89	100.0	696.3	69.54
	1,000.0	695.7	694.8	0.8	-	69.57	99.87	100.0		
ROK 5	1,000.0	715.3	714.8	0.4	-	71.53	99.93	100.0		
	1,000.0	708.6	708.1	0.4	-	70.86	99.93	100.0	706.37	70.58
	1,000.0	695.2	694.6	0.5	-	69.50	99.91	100.0		
CK 73-3-2-2	1,000.0	699.9	698.1	0.8	-	69.99	99.74	100.0		
	1,000.0	685.4	684.6	0.8	-	68.54	99.90	100.0	69.60	69.87
	1,000.0	702.6	701.9	0.6	-	70.26	99.90	100.0		

$M_d$ : Mass of dried rice,  $M_m$ : Mass of milled rice,  $M_w$ : Mass of whole grain rice,  $M_b$ : Mass of broken grains,  $M_u$ : Mass of unmilled rice,  $m_a$ : Average mass of milled rice,  $M_{aw}$ : Average mass of whole grain,  $w_{cy}$ : Whole grain efficiency,  $d_{cy}$ : Dehusking efficiency,  $M_r$ : Milling recovery

## Conclusion

The Burma Rice Processing Factory is the first complete indigenous Rice Processing machinery package that has been established in the country by the National Cereals Research Institute after elaborate research work on the development of all components of the plant.

Results on performance of the various machines and equipment in the plant clearly show high efficiencies. The whole-grain efficiency of over 99 % and over-all milling recovery of about 69.0-71.5 % are very ideal as it compares favourably with the milling recovery of 70-72 % recorded by the modern rice mills in the world.

The equipment was also observed to be sturdy, compact and rugged as breakdown recorded during the test-run period was very negligible.

All the equipment was simple to operate and maintain. The federal government of Nigeria has been urged to utilize this opportunity by encouraging individuals and co-operative farmers and agricultural business and oriented entrepreneurs to adopt this technology in order to boost rice production.

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*(Continued from page17)*

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# Development and Performance Evaluation of a Garlic Bulb Breaker



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## Abstract

Garlic (*Alliums sativum*) has been used as a food, a condiment, and for medicinal purposes for many centuries. Garlic bulb breaking is the unit operation through which cloves are separated to facilitate further processing. Conventional methods of clove separation are very laborious and time consuming. A low cost and highly efficient garlic bulb breaker was developed and evaluated for its performance and techno-economic feasibility. The developed garlic bulb breaker consisted of beater cylinder, concave, aspirator, power transmission unit and feeding chute. A 0.37 kW single-phase AC motor was used for operating the beater cylinder and aspirator with the help of belt and pulley arrangement. An aspirator was used to clean the cloves by separating skin, stem and root parts. The material collected from the trough was separated into different fractions (viz. single cloves, clump of two or three cloves, broken and crushed cloves).

Average output of 800 kg/hr and separation efficiency of 92.16 per-

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cent were obtained with a rubber strip as a padding material at an optimum speed of 340 and 135 rpm of beater and aspirator, respectively. Maximum separation of individual cloves with minimum damage of 1.1 percent and optimal removal of skin and root fraction was observed at optimized parameters. The garlic bulb breaker was found techno-economically feasible with operating cost of Rs.0.05/kg as compared to Rs.2.25/kg for manual operation for clove separation. Return on investment was calculated to be 411 percent, with pay back period of three months.

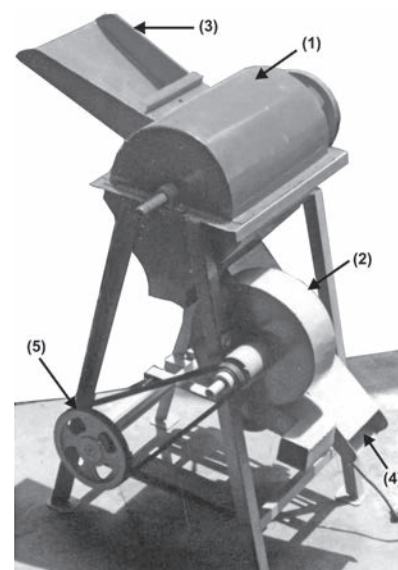
## Introduction

Garlic (*Alliums sativum*) has been used as a food, a condiment, and for medicinal purposes for many centuries. Garlic is still probably nature's most powerful medicinal plant. It is recognized to have remarkable preventive and curative abilities. Garlic is mainly used as aromatic spices and pickles as it has digestive, carminative and anti-rheumatic properties. It has long been used in ayurvedic formulation for curing lungs, healing intestinal ulcer and checking muscular pain and giddiness. The alliin is found within the mesophyll cells. Also, in the garlic clove around the phloem, in the cells

around the vascular bundles, an enzyme called alliinase is present. When garlic cloves are crushed, the combination of these two produces alliin and other thiosulphonates. The largest concentration of alliin is actually found in garlic and that is why garlic is considered the main source of alliin. The alliin appears to be effective against *E. coli*, *Staphylococcus aureus*, *Clostridium perfringens* and *Salmonella* spp.

India is one of the leading garlic producing countries. Area under cultivation and production in India, during 2002-2003 was 116 thousand

**Fig. 1** Developed garlic bulb breaker



1: Beater cylinder, 2: Blower, 3: Hopper, 4: Outlet, 5: Transmission system

hectares and 438 thousand tones, respectively. The production of garlic in Rajasthan was 75 thousand tones, which shares 17 percent of total production of the country (www.indianspices.com).

Garlic processing involves various unit operations such as curing, cleaning and grading, storage, bulb breaking, clove separation and peeling, dehydration, size reduction, packing, product formation etc. The most important part of the garlic plant is the compound bulb. Each bulb is made of 6-26 cloves with average weight of 5 grams. Bulb loosening is the unit operation through which cloves are separated to facilitate further processing. Breaking of the garlic bulb requires special care and skill due to the typical physical characteristics and presence of essential volatile oils in the epidermal cells imparting its characteristic aroma of garlic. Conventionally, separation of garlic cloves is performed by rubbing the bulb between palms, against jute bags or by beating with a wooden stick. These methods are very laborious and time consuming (Mudgal et al., 1998).

Considering the increasing demand for garlic products in domestic and export markets, a low cost and efficient garlic bulb breaker is highly needed. Therefore, a mechanical garlic bulb breaker was developed and its performance evaluated.

## Material and Methods

The separation of cloves from garlic bulbs can be achieved by striking bulbs or by rubbing on a hard surface. During separation of cloves most of the energy is absorbed on detaching the cloves from the root, inner stem and husk lining. Using the principle of the threshing process in the classical rasp-bar and toothed threshing unit, a garlic bulb breaker was developed.

The developed garlic bulb breaker is shown in **Fig. 1** and detailed dimensions are given in **Fig. 2**. A cylindrical beater of 380 mm length and 215 mm diameter was selected to achieve the required capacity of 800 kg/hr. Six concave shaped stainless blades were provided between batons in opposite direc-

tion so that the garlic bulbs could be spread evenly over the entire length of cylindrical beaters. The top surface of the batons and concave blades was covered by padding material to reduce the injuries to the cloves. Three padding materials (viz. rubber strip, coir mat and canvas cloth) were used during the study. The beater was mounted on a mild steel shaft of 20 mm diameter. Based on the average size of bulb and clove (30 and 12 mm, respectively) the grated concave of stainless steel round bars of 6 mm diameter was fabricated with a spacing of 15 mm and the clearance between beater cylinder and bars varied from 25 mm at the inlet to 15 mm at the outlet slit.

A horizontal feeding chute 240 × 90 mm was provided at the center of the upper cover of the beater for feeding the garlic bulbs. A trapezoidal shaped collecting trough with a narrow bottom outlet for the attachment of a suction pipe of the blower was provided at the lower side of the grated concave. A straight blade type centrifugal aspirator with a blade of 62 mm width and 335 mm diameter was selected for cleaning the material coming out from the concave (Sahay and Singh, 1994). The lightweight fraction (i.e. skin, root and rotten cloves) could be separated through the blower so as to collect clean cloves beneath the machine in a bag or container. A single phase, 0.37 kW, 1,440 rpm AC motor was used as prime mover for different units of the machine.

**Table 2** Effect of the blower speed on cleaning of cloves

Speed of blower, rpm	Weight of cloves collected from husk outlet		Weight of husk and root in separated cloves	
	g	%	g	%
68	13	0.30	84	21.00
90	16	0.37	35	10.00
135	20	0.46	17	5.25
180	48	1.12	11	2.75
570	96	2.25	5	1.25

Weight of sample = 5,000 g, Moisture content of bulb = 63 %

**Table 1** Effect of beater cylinder speeds on separation of cloves

Cylinder speed, rpm	Time required for bulb breaking, s	Weight of separated fraction, g				Efficiency, %
		Single cloves	Clumps of cloves	Crushed cloves	Husk and root	
180	27	3,100	1,400	-	450	68.10
225	26	3,380	1,100	-	452	74.10
270	25	3,500	670	297	451	76.85
340	24	3,506	610	360	450	77.00
360	23	3,510	590	384	451	77.10
450	21	3,290	620	510	450	72.30
600	20	3,320	620	590	452	72.80

Weight of sample = 5,000 g, Padding material = nil, Moisture content of bulb = 63 %, Thickness of beater = 15 mm

A belt and pulley arrangement were used for transmitting power to the beater cylinder and aspirator.

## Experimental Technique

Preliminary trials at different beater cylinder and blower speeds were conducted to optimize their speeds. On the basis of optimum separation and cleaning and minimum crushing and possible material loss the speed of different units was selected. The effect of padding materials (viz. rubber strip, coir mat and canvas cloth) on separation efficiency was also observed by conducting experimental trials at optimized beater and blower speed.

Bold (> 25 mm) and healthy bulbs of local variety were selected from the raw sample for the study. A test sample of 5,000 g was used for different trials. The material collected from the trough was separated into different fractions (viz. single cloves, clumps of cloves, broken and crushed cloves). The weight of these fractions was recorded for each experiment and mean values were used for further calculations. The clove separation efficiency ( $\mu$ ) was calculated as:

$$\mu (\%) = \left[ \frac{\text{Weight of single separated cloves}}{\text{Weight of sample}} - \frac{\text{Weight of skin, stem and roots}}{\text{Weight of sample}} \right] \times 100 \dots\dots\dots(1)$$

Each observation was replicated ten times to study the effect of padding materials (viz. rubber strip, coir mat and canvas cloth) on bulb breaking and clove separation efficiency. The standard procedures

were used for calculating the cost of operation, return on investment, pay back period and break-even point (Kachru et al., 1986).

## Results and Discussion

Effect of beater cylinder speeds on separation of cloves is given in Table 1. Data indicate that time required for separation decreased with increase in beater cylinder speed. Maximum separation of single cloves was achieved in the range of 270-360 rpm of beater cylinder. The speed on higher side caused damage to cloves whereas on the lower side it was unable to break the bulb and separate cloves. This result is in confirmation with findings of Jain et al. (1998) who also observed the

maximum clove separation at cylinder speed of 310 rpm. Therefore, the optimum speed for cylindrical beater was taken as 340 rpm.

Table 2 shows the effect of the blower speed on cleaning of cloves. The weight of cloves collected from husk outlet and the weight of husk and root in separated cloves were 20 g and 17 g, respectively, at the blower speed of 135 rpm. The speed on the higher side caused loss of cloves, whereas on lower side, it was unable to separate the husk and roots. Therefore, the optimum blower speed of 135 rpm was selected for conducting trials.

### Effect of Padding Material on Separation and Crushing of Cloves

The effect of three padding materials (viz. rubber strip, coir mat

Fig. 2 Dimensional details of garlic bulb breaker

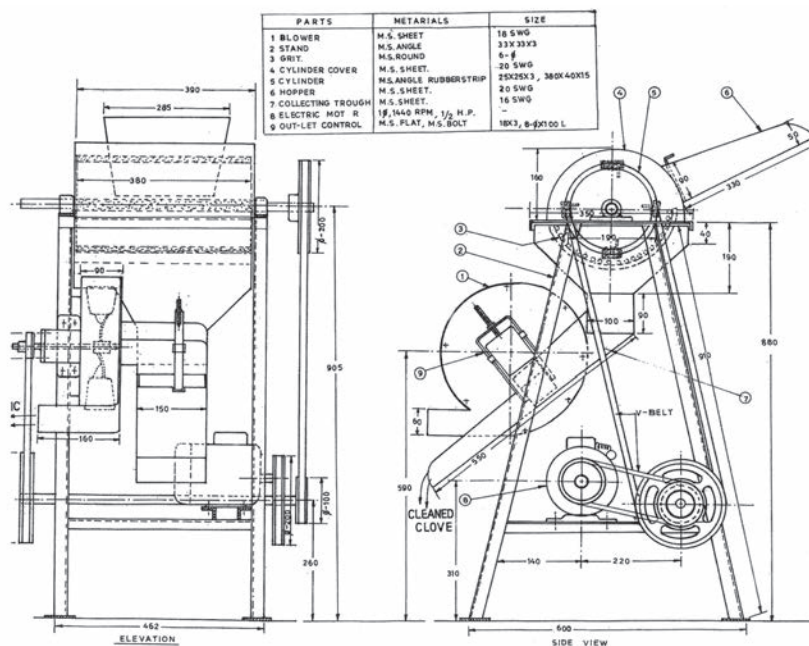


Table 3 Effect of padding material on performance of garlic bulb breaker

Padding material	Time required to break the bulbs, s	Weight of separated fraction, g					Efficiency, %	Capacity, kg/hr
		Single cloves	Clumps of cloves	Crushed cloves	Cloves of collected with husk	Husk and root		
Rubber strip	20.25	4,289.5	272.0	51.4	18.7	396	92.61	888.9
Canvas cloth	21.15	3,954.0	522.0	201.4	18.5	385	84.20	851.0
Coir mat	24.95	3,713.0	672.0	151.4	18.5	379	81.52	721.4

Weight of sample = 5,000 g, Speed of cylindrical beater = 340 rpm, Speed of blower fan = 135 rpm, Moisture content of bulb = 63 % , Thickness of padding material = 15 mm

\*Means of ten replications

and canvas cloth) on separation efficiency was evaluated at optimum beater and blower speeds of 340 and 135 rpm, respectively.

**Table 3** shows that the maximum clove separation efficiency with maximum output was obtained with rubber strip padding followed by canvas cloth and coir mat. The separation efficiency was observed as 92.61, 81.52 and 84.20 percent with rubber strip, coir mat and canvas cloth, respectively. This might be due to the fact that sufficient impact force was obtained to break the bulb without significant crushing of cloves with rubber strip as a padding material. The variation in output might be due to characteristics of padding material causing different amount of impact and movement of material. The maximum separation efficiency (92.61 %) and minimum crushing (51.4 g out of 5,000 g i.e. 1.00 %) of garlic cloves were observed with the rubber strip as a padding material.

#### **Techno-Economic Analysis**

The cost of the garlic bulb breaker with the prime mover was Rs.9,900/-. The cost of clove separation was Rs.0.05/kg of bulb, which was quite low in comparison to the manual method of clove separation (Rs.2.25/kg). The break-even point in terms of annual hours of operation, quantity to be handled and percentage of installed capacity were

observed to be 220.75 hrs, 141.28 tones per year and 12.26 percent, respectively. The pay back period of the machine was calculated to be three months, with return on investment of 411 per cent. The use of the machine can generate 1,400 man-hours per year on capital investment of every Rs.10,000/-. The developed machine was simple in construction and easy in operation and can easily be fabricated by using locally available materials and artisans. Operation of the machine did not require any specific trained persons.

#### **Conclusions**

On the basis of results, the following conclusions were drawn:

1. Beater cylinder speed had significant effect on separation of single cloves. Maximum separation of single cloves was achieved in the range of 270-360 rpm of beater cylinder speed. The speed on the higher side caused damage to cloves whereas on the lower side it was unable to break the bulb and separate cloves.
2. The number of cloves collected from husk outlet and the weight of husk and root in separated cloves were minimum at the blower speed of 135 rpm. The speed on the higher side caused loss of cloves whereas on the

lower side unable to separate the husk and roots.

3. Maximum separation (92.61 %) and minimum crushing (1.00 %) of garlic cloves were observed with the rubber strip as a padding material.
4. Cost of operation of the developed machine was quite low in comparison to the manual method of clove separation.

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# Mechanized Rice Cultivation in Bangladesh: Past Experiences and Future Potentials

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## Abstract

In Bangladesh, cultivable land is decreasing due to industrialization and urbanization but food demand is increasing with the increase of population. Moreover, farm labourers are migrating to non-farm jobs resulting in acute labour shortage in the peak period of farm operations. Therefore, farm mechanization becomes essential for the food security of the country. Bangladesh Rice Research Institute (BRRI), Bangladesh Agricultural Research Institute (BARI), Bangladesh Agricultural University (BAU), Bangladesh Agricultural Development Corporation (BADC) and other GOs and NGOs in collaboration with the local manufacturers have been trying to introduce farm mechanization technologies in the country for the last three decades. There are some success of mechanization already found in tillage (60 % by power tiller and tractor), irrigation (57 % by deep tubewell, shallow tubewell and low lift pump). BRRI has developed and adopted a number of farm machines (i.e. seeders, weeders, threshers and winnower at selected sites and industries. Some of the machines

such as hydro tiller, reapers (power tiller mounted and self-propelled) and dryers are under farm level trials. Awareness of farmers on using farm machines were developed in selected sites. As a result, farmers invested about Tk.1,448,500 to purchase BRRI machines from BRRI enlisted manufacturers during 2004-2006 and these were found profitable to use on rental basis. There are some challenges ahead to develop and adopt an appropriate rice transplanter, reaper for-low lying and marshy land, dryer, rice processing and renewable technology throughout the country for increased food production, poverty reduction and employment generation as well as improvement of socio-economic conditions of the farmers of Bangladesh.

## Introduction

The population of Bangladesh has been increasing and at the same time agricultural land has been decreasing alarmingly. Increasing demand for food and nutrition for the country's 138.8 million population is growing at the rate of 1.43 % per

year, which puts pressures on land for increased production through double or triple cropping (Bangladesh Arothonaitik Sameekha, 2006). This requires more power inputs per unit area and farmers are looking for alternative power sources to meet the demand. It is evident from research results that land productivity is directly proportional to the power input to agriculture. In Bangladesh, presently over 70 % of the energy for 9.6 million hectares of cultivable land mainly comes from human and animal sources. The average drought power shortage is about 30-35 % and it increases up to 45 % during the peak periods.

Rice production is vital to Bangladesh economy and agriculture engages 52 % of the total agricultural labour force. Besides, rice production continues to be one of the important sources of livelihood accounting for 76 % of the people's average calorie intake and 66 % of protein intake (BBS, 1996). It has doubled since independence without further increase in rice area. Although modern varieties cover almost 74 % of the total rice cropped area, the yield level still lags behind other Asian countries (BRRI Inter-

nal Review, 2005).

For further increase of the production per unit land area, it is very important to increase the cropping intensity which may be attained through the adoption of appropriate farm mechanization technologies. Moreover, rural labour force has started to shift from the agricultural to the industrial sector, creating acute shortage of labour during peak planting and harvesting periods. In case of occurrences of flood, drought and other natural calamities mechanization is the only option, which can handle problems for land preparation, crop establishment, harvesting, threshing and drying of crops timely.

BRRRI, BARI, BAU, BADC and other GOs and NGOs in collaboration with the local manufacturers have been trying to introduce farm mechanization technologies in the country for the last three decades. Drying is one of the crucial problems in post harvest processing of farm produce, especially seed, in BADC, Department of Agricultural Extension (DAE). BRRRI can fulfill only 12-15 % of the total seed requirements (Harun et al., 2003). Yet appropriate transplanter, reaper, mini combine and drying machines need to be developed and adopt for different agro-ecological conditions of Bangladesh.

Foreign farm machines are very costly and can not be adopted in our fragmented land, agro ecological and socio-economic conditions. Farm Machinery and Post Harvest Technology (FMPHT) Division of BRRRI so far has developed about 25 technologies. About seven popular technologies were demonstrated in about 21 districts of Bangladesh through "Popularizing Agricultural Machinery Augment Mechanized Rice Cultivation in Bangladesh (PAMP)" and other projects. In order to address the above need some machines and technologies have been developed and adopted that are enumerated sequentially from land

preparation to storage.

### **Land Preparation**

For land preparation, there has been a remarkable shift from the bullock ploughing to the mechanized option during the last two decades. At present, power tiller is the predominant option for land preparation, which covered about 55 % of the cultivable land; however, tractor and bullock ploughing covered about 5 % and 40 % land, respectively. Presently 300,000 power tillers and 10,000 four wheel tractors are in use by the farmers. Hydrotiller is suitable for land preparation in marshy land. The capacity of hydrotiller is about 35-40 dec/h. A power tiller operated leveler has been developed at BRRRI for proper leveling of fields suitable for seedling transplanting and also for the operation of drum seeder.

### **Seeding and Planting**

Seeding and planting operations still depend on traditional methods. Rice transplanting is a highly labour intensive farm operation. The total labour requirement for rice production in 1 hectare of land is 156.2 man-days of which 44.5 man-days are consumed by seedling raising and transplanting that is 28.48 % of the total labour requirement (Rahman, 1997). For manual transplanting in rows, approximately 400 man-hr/ha labor is required which is roughly 30 percent of the total labor requirement for rice production (Islam, 1998). The shortages of labour are being observed during transplanting season. The yield losses due to delayed planting have been shown to be 60.0, 55.4 and 9.0 kg/ha/day in Boro, Aman and Aus season, respectively (Sattar, 1999). Therefore, a means of faster and timely planting of rice is an utmost need.

A 2-row Japanese rice transplanter was evaluated at BRRRI farm. The work rate was 0.12 ha/hr and the work quality were satisfac-

tory. However, instead of seedling transplanting, the direct seeding of sprouted seed by drum seeder was in the pilot testing stage in the farmer's field with the collaborative effort of BRRRI and DAE personnel. The field capacity of a drum seeder was about 5.67 man-h/acre. The drum seeder technique of crop establishment proved the reduction of rice production cost by Tk.4,000-5,000/ha compared to the existing transplanting practice in terms of labour saving (Husain, 2006; Personal communications). The drum seeder had the potential to cover about 30 % of cultivable land due to some limitation, i.e. proper field leveling, seasons, bird damage, length of sprouted seed, elimination footprint, etc. Proper training on the operation and management of the drum seeder can enhance its field level the adoption. Two units of roller type footprint (FP) levelers for drum seeder were designed and fabricated. One was made of M.S. sheet (4.0 kg weight) and the other was made of G.I. pipe (7.0 kg weight). Both the levelers performed well in low land conditions. Five local manufactures are presently producing the drum seeders and their qualities are quite comparable to that of the imported seeders. The cost of a locally produced drum seeder ranges between Tk.2,500-3,000. At present, more than 10,000 drum seeders are being used by the farmers. Moreover, for dry land sowing of rice, a power tiller drawn seeder namely BHT seeder is effective. The field capacity of a BHT seeder is 0.12-0.15 ha/h. It can save about Tk.1,400 per ha compared to traditional sowing. About 100 units of the BHT seeder are in use by the farmers, mainly for sowing wheat, onion and jute.

### **Irrigation**

Application of irrigation in proper time is a prerequisite for expected crop yield. At present, about 4.8 M ha land is under irrigation out of the total arable land (8.4 M ha) by dif-

ferent modes of irrigation. Presently 71 % of the irrigated land is covered by ground water and the rest (29 %) is covered by surface water. Among the different irrigation options, shallow the tube-well (STW) plays a notable role, which covers about 53 % land area. It is reported by Irrigation and Water Management division of BRRI that the aforesaid area is being irrigated by 1,100,000 (STW), 100,000 (LLP) and 37,000 (DTW).

### **Weed Control**

Hand weeding method is a common practice for weed control in Bangladesh. It was reported that 8-10 % of farmers at present use herbicide to control weed. Comilla Co-operative Karkhana first introduced Japanese type push weeder in Bangladesh. BRRI, BARI and other organizations developed a weeder suitable for upland and lowland conditions. The field capacity of the indigenous weeding fork was 0.004 ha/h at a weed density of 250 weeds/m<sup>2</sup> (Islam and Haq, 1985). The operation of the rotary type weeder is possible in lowland rice fields where seedlings are transplanted in rows. BRRI has developed a weeder for lowland paddy, having a working capacity of 0.04 ha/h and costing only Tk.400. It can save about Tk.1,200 per ha compare to hand weeding. The latest version of BRRI weeder (13 cm) is suited to operate in the field sown by drum seeder. At selected sites, as high as 80 % farmers showed satisfaction over the performance of the weeder. Presently, about 200,000 units of push type weeders are being used by the farmers.

### **Harvesting**

Traditionally, farmers harvest with a sickle. The working capacity of labour with a sickle is only 0.01 ha/h. Labour shortage during crop harvesting is a regular problem in Bangladesh. BRRI, BARI, BAU and other organizations developed a power tiller and self propelled

reaper. But those reapers can not operate in low lying areas. In low lying areas, especially haor areas, the mini combine harvester can be good solution to harvest rice. The capacity of BRRI developed power tiller and self propelled reapers for harvesting rice and wheat ranged from 30-45 decimal/h. The reaper can save Tk.800 per ha compared to traditional harvesting. At selected sites, 52-88 % farmers were satisfied with the performance of the power tiller operated reaper. Presently about 40 PT mounted reapers have been using by the farmers. About 15 self-propelled reapers have been used by the farmers.

### **Threshing**

At this time, most farmers want to thresh their crop by using a mechanical thresher. Various makes and models of the mechanical thresher are widely used by the farmers. Research institutions and private entrepreneurs have developed hold-on type and through-in type mechanical threshers. The major difference in the BRRI developed through-in-type thresher and others threshers is the presence of a built-in cleaning mechanism in the BRRI threshers. Therefore, the BRRI thresher has the potential in the farmers' field. The capacity of the BRRI threshers ranged from 350-600 kg/h for paddy and 400 kg/h for wheat threshing. The benefit of using these machines is about Tk.240 per ton compared to traditional threshing. BRRI threshers were demonstrated in the farmer's field in different districts during Boro, Aus, Aman, and Wheat seasons and most farmers showed their satisfaction with the performance of BRRI threshers.

### **Cleaning**

Farmers of Bangladesh clean their dried grain in natural wind blowing with the help of Kula and electrically operated fan. This system is not workable during rains and other natural calamities. The BRRI devel-

oped motor operated winnower with a capacity of 400-500 kg grain/h is capable of saving Tk.200/ton over the traditional method of winnowing. During field demonstration, farmers showed a great response to this machine. Presently, about 500 winnower machines for cleaning grain are being used by the farmers and traders.

### **Drying**

Farmers still practice natural sun drying for drying their crops. A suitable dryer is not available at the farm level. A mechanical dryer is used on a limited scale by BADC farm and seed companies. Research institutes and BAU also developed several types of dryers and demonstrated in the farmer's field. The capacity of the BRRI seed dryer is about 250 kg paddy/batch. Fuel (electricity and rice husk) cost ranged from Tk.0.15 to 0.30 per kg of paddy. The germination capacity of dried paddy was more than 80 % after six months of storage. The BRRI seed and Vietnamese (500 kg and four tone per batch) dryers were demonstrated at different districts of Bangladesh. Vietnamese dryers had some problems of mixing ash with the grains. To overcome this problem, BRRI developed a flat bed type batch dryer of one ton per batch capacity (length 3.66 m, breadth 1.83 m, height 0.91m and fuel consumption 2.25-2.50 l/h). The drying took about 9-hour to reduce moisture content from 22.1 to 13.9 % (w.b.). As the dryer will be used only for a few months in a year, custom hire service and community based drying are recommended. BRRI scientist in collaboration with rice millers have developed processing technology of long grains aromatic paddy (BRRI dhan 37 and 38) by using sun drying technique. The paddy was dried in the sun at a temperature of 24-38 °C. The paddy was dried everyday, for 4 hours and followed by 20 hours stacking for tempering. Repeating the process for 3-4 days

to obtain the maximum removal of white belly from the dehusked rice. As a result, milling yield of 60 % was obtained, which is 5 % higher than the existing practice.

### **Storage**

Traditionally farmers stored their paddy in earthen pots, dole, jar, dhap, motka, etc. In a study, it was observed that rice grain with moisture content less than 11 % (w.b.) could be stored in a metal container up to 15 months with germination above 89 %. Paddy can be safely stored in lamofoil and viability of seed can be maintained above 89 % after one year storage. A 5-ton capacity Grain Pro Cocoon storage container (USA made) was tested at BRRRI HQ for storage of paddy seed and after one year of storage the seed viability was maintained above 90 %. Insects died inside the Cocoon due to high concentration of CO<sub>2</sub> and low level of oxygen in the hermetic storage environment. Fine and aromatic rice can be stored at 9 % moisture content in a polythene bag for 9-10 months without quality deterioration.

### **Machines Sold and Investment by the Manufacturers**

Due to the upward trend of farm mechanization, a large number of entrepreneurs have come forward to manufacture various types of farm machines that are sold to government, non-government, private organization and farmers. BRRRI enlisted manufacturers to fabricated the BRRRI weeder, BRRRI rice-wheat reaper, BRRRI open drum thresher and BRRRI rice-wheat thresher to be sold to public organizations and farmers. BRRRI provided a prototype as well as technical support. During 2004-2006, farmers invested Tk.1,448,500 to purchase BRRRI machines. Farmers were interested in investing more money on the BRRRI rice-wheat thresher than the open drum thresher as it had dual purpose use; i.e. rice and wheat could be

threshed in one machine. Moreover, the BRRRI rice-wheat thresher had a cleaning mechanism. On the other hand, it had the potential to be used on rental basis.

### **Technology Transfer**

Technology transfer as well as adoption for end users is the key to success for any kind of product. For this reason leaflets, brochures, posters, TV fillers and video were published and distributed to the end users. Manuals on the operation and maintenance of BRRRI machines were also published for distribution. Fact sheets of BRRRI farm machines were also prepared and published on the Bangladesh Rice knowledge Bank website. Agricultural scientists and extension personnel as well as farmers can benefit from these information and extension materials.

### **Constraints of adoption and popularization of farm machines**

- Lack of awareness among farmers for use of these machines in agricultural operations.
- Knowledge gap of manufacturers, operators/farmers on manufacturing, operation, repair and maintenance of farm machines.
- Capital shortage of manufacturers for manufacturing quality machines.
- Absence of effective linkages among the researchers, manufacturers, farmers, and extension personnel.
- Farmers do not get proper value of agricultural produce compared to their production cost.
- Initial cost of farm machines is very high.
- Limited days of usefulness of farm machines.
- Cooperative farming is not working effectively.

### **Future policy implications for mechanization**

- DAE may help to generate statistical data on farm machinery

such as power tiller, drum seeder, weeder, sprayer, harvester, thresher, drier, winnower and storage structures like other machines in block level.

- Agricultural Training Institutes (ATI) under DAE should have a definite curriculum on Farm Mechanization and Post harvest Technology. One set of potential farm machines may be provided for each ATI training purpose.
- Courses on Farm Machinery and Post harvest Technology for rice production and processing should to be included in the training programme of the Youth Training Centre and Vocational Training Institutes of Ministry of Youth Sports and Education.
- Promote credit facilities for farm and agro processing machines at low interest to individual farmers and farmer cooperatives for the acquisition of agricultural machinery through government, non-government and private financial institutions, i.e. Bangladesh Krishi Bank, Commercial Banks, Grameen Bank, etc.
- Farmers need subsidy on farm and agro processing machinery due to the high initial cost.
- Insurance provision of farm and agro processing machinery may be helpful to the farmers.
- Government may provide a fair price of farm products to the farmers.

### **Expected Outcome of Farm Mechanization**

- Total rice production will be increased due to less postharvest loss and reduced yield gap due to timely land preparation, planting, seeding, threshing, drying and cleaning operations.
- Labour shortage at peak planting and harvesting period would be minimized and physical drudgery of farmers would be reduced.
- Self employment will be gener-

ated through the manufacturing, renting, service, repairing and maintenance of farm machinery which will create a positive impact on the industrialization and help the farmers to improve their socio-economic status.

- For the implementation of farm mechanization programmes farmers groups/co-operative will be established for efficient use of farm machinery.

## Conclusions

Among all the farm operations, a notable level of mechanization is achieved in tillage (60 %) and irrigation (57 %). Farmers can reduce production cost and postharvest loss using farm machines. Direct seeding of paddy by drum seeder reduced rice production cost by Tk.4,000-5,000 per ha and it is in the pilot testing stage in the field. At present five local manufactures are producing the seeder and their qualities are quite comparable to that of the imported seeder.

BRRRI developed machinery, i.e. weeder, reaper, thresher and winnower, were demonstrated in the field and the result revealed that the

rental service is very much effective for profitable agriculture to the farmers. As a result, farmers invested about Tk.1,448,500 to purchase farm machinery during 2004-2006.

Future research on an appropriate rice transplanter, mini combine for low lying and marshy land, appropriate drier, fine rice processing and renewable technology is to be strengthened.

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# Status of Farm Power Availability in the Selected Villages of Jammu District (J & K States)

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## Abstract

A survey conducted in 40 villages of Jammu District of Jammu region (J & K State) revealed that the average unit farm power availability (kW/ha), draught animal pair intensity (ha/pair), average land holding (ha), cropping intensity (per cent) and irrigation intensity (per cent) were 2.58, 5.02, 0.99, 201.16 and 62.23, respectively. The availability of draught animals, tractors, electric motors and diesel engines were 572.38, 49.09, 152.04 and 21.22 per thousand ha of cultivable area, respectively. The unit farm power availability ranged from 0.0-0.5, 0.5-0.75, 0.75-1.0, 1.0-1.234, 1.234-2.0, 2.0-3.0 and 3.0-12.0 kW/ha in 7.5, 2.5, 10.0, 10.0, 7.5, 30.0 and 32.5 percent of villages, respectively. Seventy percent of the villages have unit farm power availability above the National average of 1.231 kW/

ha. The draught animal pair intensity was 0-2, 2-5 and more than 5 ha/pair in 20.0, 45.0 and 35.0 percent of the villages, respectively.

## Introduction

The Jammu and Kashmir state is located in extreme north of India between 32°17'-37°6' N latitude and 73°26'-80°30' E longitude. The Jammu region of the state comprises of six districts namely Jammu, Kathua, Udhampur, Rajouri, Doda and Poonch having a total geographical area of 1.794 M ha out of which 0.652, 0.389, 0.226, 0.229 and 0.298 M ha area is under forests, cultivable, non-Agril use, barren undulated and other uses, respectively. Jammu district of the state has total geographical area of 0.320 m ha out of which 0.040, 0.107, 0.031, 0.070 and 0.288 M ha area are under

forests, cultivable, non-Agril use, barren undulated and other uses, respectively (Anonymous, 2002). The wheat, rice and maize are the main cereals grown in the district with an average yield of 17.91, 13.21 and 20.17 q/ha, respectively. The yield of these crops is quite low as compared to their potential. Therefore, in order to increase production and productivity and real income of the farmers, there has to be modernization of agriculture for removal of human drudgery, improvement and optimum use of various sources of energy, input-output ratio, timeliness of operation and diversification of labour use. In the past 33 years, for producing 1 tonne of food, the total energy consumption in India has increased by 5,951 MJ, and operational energy by 3,404 MJ, with an increase in crop productivity by 0.474 t/ha (Dipanker, De; 2005).

The unit power availability in

**Fig. 1** View of tractor operated cultivator (nine tines) in operation



**Fig. 2** View of tractor operated offset disc harrow (six discs) in operation



**Fig. 3** View of animal drawn mould board plough (Tawi plough)



India was 0.30 kW/ha in 1971 that was 45, 40 and 15 percent from animal, mechanical and manual power, respectively, which has increased to 1.231 kW/ha in 2001 dominated by mechanical (85 percent) and followed by animal (9 percent) and manual power (6 percent), and is expected to be 1.50 kW/ha by 2005 (Ali, Nawab; 2005). However, for intensive farming, it is required to be 2.0 kW/ha (Alam, Anwar; 2005).

Therefore, the current investigation was under taken to assess the status of farm power availability in the forty selected villages of Jammu district of Jammu region (J & K State).

## Materials and Methods

A survey was conducted in 40 villages randomly selected in Jammu District (Tehsil Jammu-15, tehsil Samba-13 and tehsils R. S. Pura & Bishnah-12) of J & K State on a pre-devised proforma. Data were analyzed to assess the status of average land holding (ha), cropping intensity (percent), farm power availability (kW/ha), draught animal pair intensity (ha/pair), tractor intensity (number/thousand ha) and irrigation intensity (percent) in the selected villages. The power equivalence of human and draught animals were taken as 0.05 kW/human and 0.25 kW/animal, respectively, whereas the power equivalence for tractors, electric motors and diesel pumps were taken as per their rated capacity (Singh, 1997).

(percent), farm power availability (kW/ha), draught animal pair intensity (ha/pair), tractor intensity (number/thousand ha) and irrigation intensity (percent) in the selected villages. The power equivalence of human and draught animals were taken as 0.05 kW/human and 0.25 kW/animal, respectively, whereas the power equivalence for tractors, electric motors and diesel pumps were taken as per their rated capacity (Singh, 1997).

## Results and Discussions

The study revealed that there was a high level of tractorisation in the irrigated belt of the Jammu district. The draught animals have been replaced by tractor power to a great extent in the irrigated belt of district. The tractor driven cultivator (Fig. 1) and offset disc harrows (Fig. 2) are the main tillage implement. Animals are generally used in pairs along with equipment such as the country plough, tawi plough (Fig. 3), soil stirring plough (Fig.

4), 3/5 tines cultivators and planker. Broadcasting of seed and fertilizer, followed by plowing and planking generally does the sowing in tractor farms of the irrigated area whereas Kera method of sowing is adopted in bullock farms of the rainfed area (Fig. 5) followed by planking (Fig. 6). The use of knapsack sprayer is prevalent for application of chemicals. Harvesting is mostly done by manual power. The thrashing of wheat is almost mechanized. The transplanting of rice, harvesting (Fig. 7) and thrashing (Fig. 8) are still done manually.

### Land Holding Pattern

The data (Table 1) revealed that the overall average land holding was 0.99 ha with R.S. Pura and Bishnah tehsils having the highest (1.19 ha) followed by Samba (0.90 ha) and Jammu (0.89 ha). The Kalyan village in R.S. Pura and Mandi Gurgalian village in Samba tehsil had the highest (2.78 ha) and the smallest (0.34 ha) average land holding. The average holding size in country was 2.26 ha in 1970-71 and was expected to be 0.75 ha by 2030 (Dipanker, De; 2005).

### Major Crops and Cropping Intensity

The rice-wheat/mustard/fodder, maize-wheat/mustard and maize-wheat/upland rice were the main crop rotations being adopted in 60, 25 and 15 percent of the villages, respectively (Fig. 9). Crops like mash, till, kidney beans, barley, potato, vegetable and rajmash were

Fig. 4 View of tillage operation with animal drawn soil strring plough



Fig. 5 View of wheat sowing using animals by Kera method of sowing



Fig. 6 View of planking operation after wheat sowing using animals



Fig. 7 View of paddy harvesting and spreading in windrows



Fig. 8 View of paddy thrashing operation by beating



also cultivated in some of the selected villages. The average cropping intensity was highest in Jammu (220.22 percent) followed by R.S. Pura (198.88 percent) and Samba (184.39 percent) tehsils. The overall cropping intensity was 201.16 percent (Table 1).

### Farm Power Availability

The draught animals and humans were the main sources of power in 12.5 percent of the selected villages whereas tractors, draught animals and human were the main source of power in 87.5 percent of the selected villages of the district. The availability of draught animals, tractors, electric motors and diesel engines were 572.38, 49.09, 152.04 and 21.22 per thousand ha of cultivable area (Fig. 10). There was no power tiller in these villages.

### Draught Animal Pair Intensity

The Draught Animal Pair intensity was 0-2, 2-5 and 5-10 ha/pair in 20.0, 45.0 and 35.0 percent of the villages, respectively (Fig. 11). The average draught animal power intensity was 5.02 ha/pair with the Gangial village having the highest (30.10 ha/pair) and Pangali village having the lowest (0.79 ha/pair) (Table 1). Mishra and Singh (1994) reported that a pair of bullocks with a complete set of implements can cultivate 2.0 ha area for best production. Twenty percent of the selected villages have sufficient draught animals. The use of animals was prevalent in Dansal block in Jammu tehsil and Samba tehsil. However, the draught animal availability was very low in R.S. Pura and Bishnah tehsils. The draught animal power was supplemented by tractor power in 87.5 percent of villages. The average draught animal pair intensity in the selected villages was highest in R. S. Pura and Bishnah (5.55 ha/pair) followed by Jammu (5.32 ha/pair) and Samba (4.20 ha/pair) tehsils.

### Tractorisation Intensity

The tractor population in the district was 49.09 per thousand ha

of cultivable area. The National tractorisation intensity ranged between 1.0-72.0 tractor/thousand

**Table 1** The unit farm power (kW/ha), irrigation intensity (%), cropping intensity (%), draught animal pair intensity (ha/pair) and average land holding (ha) in the selected villages of various Tehsils of Jammu district (J & K State).

Name of village	Unit farm power, kW/ha	irrigation intensity, %	Cropping intensity, %	Draught animal pair intensity, ha/pair	Av. land holding, ha
<b>A. Tehsil: SAMBA</b>					
1. Dhammi	0.92	0.0	198.5	1.70	0.76
2. Pangali	0.82	0.0	200.0	0.79	0.50
3. Nagola	0.43	0.0	191.6	1.36	0.93
4. Nador	0.94	0.0	200.0	1.79	0.49
5. Gangial	2.14	70.4	196.3	30.10	0.65
6. Deeli	0.40	31.5	200.0	8.73	0.36
7. Raipur Jaggir	2.97	96.5	193.4	4.72	1.02
8. Sari Rakhwalan	3.16	100.0	300.0	7.08	0.90
9. Singhe Chack	2.06	100.0	205.0	3.76	1.41
10. Surhe Chack	3.72	100.0	211.4	3.57	0.89
11. Top Manhasan	11.14	109.4	271.1	1.65	0.58
12. Shehwala	5.55	97.9	204.2	3.03	0.94
13. Jaswan	2.03	100.0	210.7	5.05	0.81
14. Morapur	3.42	100.0	300.0	3.64	1.95
15. Sehzadpur	4.66	81.6	221.2	2.83	1.13
<b>Mean (A)</b>	2.96	65.82	220.22	5.32	0.89
<b>S. Em+/-</b>	0.71	11.65	25.29	1.86	0.10
<b>B. Tehsil: SAMBA</b>					
1. Chak Banah	1.72	1.1	193.9	6.08	0.69
2. Patti	2.33	100.0	203.0	4.09	1.36
3. Smailpur	1.21	0.1	189.9	3.43	0.58
4. Badhori	1.21	0.1	189.9	3.43	0.58
5. Arzi Samba	1.10	6.3	200.0	9.34	0.58
6. Mandi Gurghalian	4.42	7.7	196.2	6.09	0.34
7. Nand	0.58	0.0	197.7	1.00	1.00
8. Kathali	1.87	6.9	140.3	3.37	1.91
9. Sujwan	0.19	86.9	100.0	8.24	0.72
10. Palli	1.42	99.9	200.0	4.06	1.16
11. Chak Bagian	4.26	31.0	198.3	1.57	0.67
12. Ramboo Rasorian	1.05	2.6	195.7	1.79	0.87
13. Daboj Shahzada	0.89	22.2	192.2	2.14	1.24
<b>Mean (B)</b>	1.71	28.06	184.39	4.20	0.90
<b>S. Em+/-</b>	1.29	39.69	29.93	2.57	0.43
<b>C. Tehsils: R.S. PURA and BISHNAH</b>					
1. Bera	4.05	98.0	198.0	7.63	1.60
2. Jasour	2.70	91.8	200.0	6.35	0.66
3. Biaspur	2.97	100.0	197.0	4.29	1.12
4. Choga	1.94	97.2	197.1	3.82	0.98
5. Rajwal	5.12	75.1	194.8	2.47	1.07
6. Rathana	2.76	100.0	200.0	6.65	0.87
7. Kalyan	3.73	100.0	200.0	8.05	2.78
8. Tref Brahmana	2.59	87.5	200.0	4.29	1.05
9. Sohagpur	2.70	100.0	200.0	3.22	1.34
10. Kool Kalan	2.33	79.1	200.0	2.43	1.27
11. Deoli	2.62	100.0	200.0	12.28	0.73
12. Mujua Lakshmi	3.19	85.1	199.6	5.06	0.78
<b>Mean(C)</b>	3.06	92.82	198.88	5.55	1.19
<b>S. Em+/-</b>	0.25	2.60	0.50	0.82	0.16
<b>D. Mean (A+B+C)</b>	2.58	62.23	201.16	5.02	0.99



ha, with an average of 15.8 being highest for Punjab (71.4) followed by Haryana (60.1), Uttar Pradesh (28), Tamil Nadu and Gujarat (12.3) and Rajasthan (9.8). Among the under developed states like West Bengal and Orissa, it was 1.5 and 1.3, respectively, whereas the world average was 19.2 (De, Dipanker; 2005). Therefore, the Jammu district belongs to districts/states of the country having better tractorisation intensity. The tractors were being used for on farm as well as off farm work. The off farm work included such things as transportation of building material.

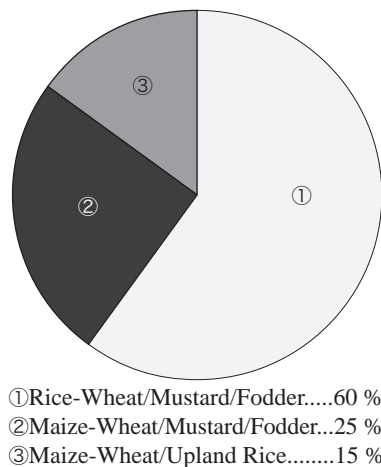
### Unit Farm Power Availability

As evident in **Table 1**, the average unit farm power availability was highest in R.S. Pura and Bishnah Tehsils (3.06 kW/ha) followed by Jammu (2.96 kW/ha) and Samba (1.71 kW/ha). The highest farm power availability (11.14 kW/ha) was reported in the top Manhasan village. The unit farm power availability ranged from 0.0-0.5, 0.5-0.75, 0.75-1.0, 1.0-1.234, 1.234-2.0, 2.0-3.0 and 3.0-12.0 kW/ha in 7.5, 2.5, 10.0, 10.0, 7.5, 30.0 and 32.5 percent of villages, respectively (**Table 2**). As such, 70.0 percent of selected villages of Jammu district have a unit farm power more than

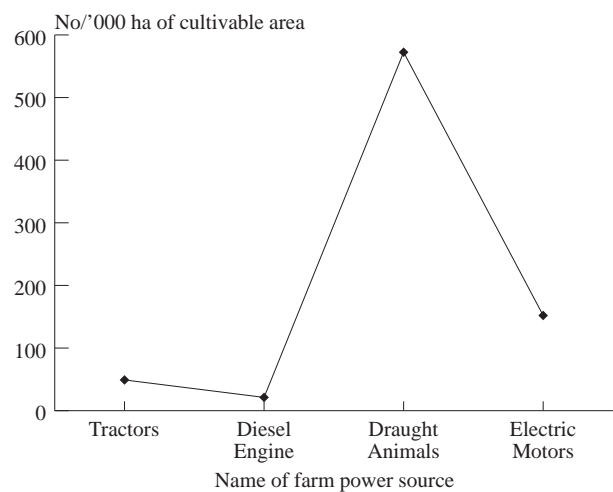
the National average (1.231 kW/ha). The farm power availability across the country was highest (4.7 kW/ha) in Punjab and lowest (0.39 kW/ha) in Orissa (De, Dipanker; 2005). Therefore, Jammu district belongs to the group of district/states having better unit farm power availability.

The overall unit farm power availability in the selected villages of Jammu district was 2.58 kW/ha that was contributed by 6.07, 90.06 and 3.87 percent animal, mechanical and manual power, respectively, (**Fig. 12**). This seemed to be adequate as compared to the overall National average (1.234 kW/ha) that was contributed 9.0, 85.0 and 6.0

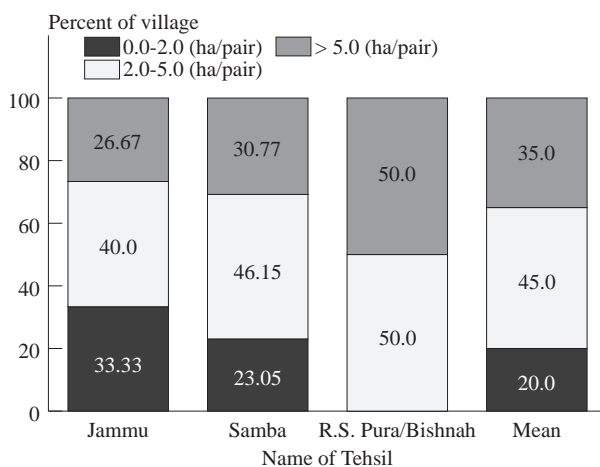
**Fig. 9** Percent area under major crop rotations in the selected villages of Jammu district (J & K state)



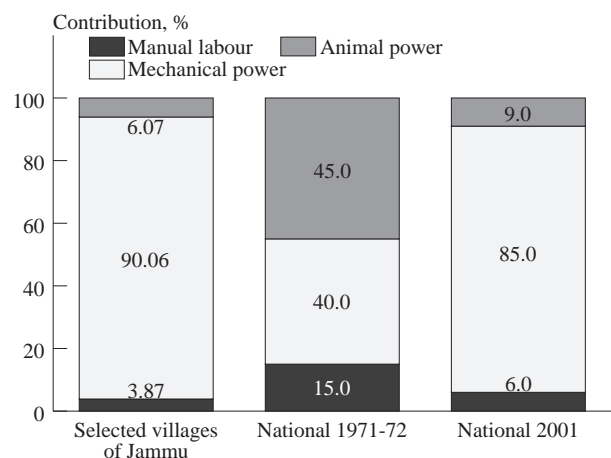
**Fig. 10** Availability of various farm power sources in the selected villages of Jammu district (J & K state)



**Fig. 11** Tehsil wise percent of selected villages of Jammu district having different draught animal pair intensity (ha/pair)



**Fig. 12** Contribution of various farm power source (percent)



percent by animal, mechanical and manual power, respectively. The requirement for intensive agriculture was 2.0 kW/ha. However, the higher average unit power has mainly been contributed by high level of tractorisation and irrigation pumps in the irrigated belt of R.S. Pura/Bishnah and Jammu tehsils of Jammu district. The average unit power was quite low in the rainfed and hilly areas where the use of a tractor was not possible due to topography, restricted accessibility, small irregular shape fields on terraces and reduced field efficiency. In order to increase cropping intensity and to reduce turn around time, high-energy inputs for field operation were required for rainfed areas.

### Irrigation Intensity

Nearly 62.23 percent area was irrigated with R.S. Pura and Bishnah tehsil having highest (92.82 percent) followed by Jammu (65.82 percent) and Samba (28.56 percent) (**Table 1**). Further, thirty percent of the selected villages in the Jammu district had less than 10 percent of the area under irrigation.

### Conclusions

1. The Jammu district belonged to districts/states of the country having better tractorisation intensity (49.09/thousand ha of cultivable area) and unit farm power availability (2.58 kW/ha).
2. The unit farm power availabil-

ity ranged from 0.0-0.5, 0.5-0.75, 0.75-1.0, 1.0-2.0, 2.0-3.0 and 3.0-12.0 kW/ha in 7.5, 2.5, 10.0, 17.5, 30.0 and 32.5 percent of villages, respectively.

3. Seventy percent villages had unit farm power availability more than the National average (1.231 kW/ha).
4. Draught animal pair intensity ranged between 0-2, 2-5 and more than 5 ha/pair in 20.0, 45.0 and 35.0 percent of the villages, respectively.

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**Table 2** Tehsil wise percent of selected villages in Jammu district having different available unit power

Unit power	Selected villages in various Tehsils of Jammu districts, %			
	Jammu	Samba	R.S. Pura/Bishnah	Mean
0.0-0.5	0.0	7.69	0.0	7.5
0.5-0.75	0.0	7.69	0.0	2.5
0.75-1.0	33.33	7.69	0.0	10.0
1.0-1.234	0.0	26.38	4.76	10.0
1.234-2.0	0.0	19.79	3.57	7.5
2.0-3.0	26.67	7.69	58.33	30.0
3.0-12.0	40.0	23.07	33.34	32.5

# Indoor Storage of Paddy-Rice in the Lowlands of Papua New Guinea

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## Abstract

Papua New Guinea, (PNG) is situated in the South Pacific between 2° and 12° South latitude and 141° and 156° East longitude. Several islands constitute 20 provinces and 67 % of the land is hilly with steep slope. There is a diverse climatic condition prevalent from lowlands to highlands region of Papua New Guinea. The temperature in the lowlands is always between 30 to 36 °C with high humidity of about 70 to 90 %. Rice production is relatively a new venture in PNG and majority of rice consumed in the country is imported from elsewhere. However, many subsistence farmers are growing

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rice on a limited scale. There is a growing tendency among the farmers to take the paddy rice for milling after harvesting and threshing. But rice mills are not readily available. Thus, paddy-rice has to be stored both for milling at a later stage or for seed purposes.

A study was conducted on storage of rice using indoor storage-structures for subsistence farmers. Six storage structures namely, metal bins, cement plastered bins, mud plastered bins, bamboo strip plain bins, polythene bags and copra bags were used to store TCS-10 variety of paddy-rice. The capacity of each structure was about 75 kg. The paddy-rice was stored for 148 days and the suitability of each type of structure was observed and related data were analysed. The cement plastered and mud plastered bins were the most suitable for storage of paddy-rice in the hot and humid

region of Papua New Guinea.

## Introduction

Rice is relatively a new crop introduced in Papua New Guinea although some primitive variety may have existed in the country. It is estimated that about 10,000 tonnes of rice are grown annually by the subsistence farmers. The harvesting is done manually and so is threshing and winnowing. There is no commercial farming of rice as in the case of coffee, oil palm, cocoa and sugarcane.

The National Agricultural Research Institute has released some new varieties of rice suitable for subsistence cultivation. Losses occur right from harvesting stage and it is essential to harvest paddy rice on time in order to avoid grain losses which may result from feed-

**Fig. 1** View of storage structures; (T<sub>1</sub>) Metal bin, (T<sub>2</sub>) Polythene bag and (T<sub>3</sub>) Mudplastered bin



**Fig. 2** View of storage structures; (T<sub>4</sub>) Bamboo strip plain bin, (T<sub>5</sub>) Cement plastered bin and (T<sub>6</sub>) Copra bag



ing by rats, birds, insects and from shattering and lodging. According to Datta (1981), early and late harvests are detrimental to crop yield and milling return. In addition, the percent germination was found to be very low if the grain is harvested too early, (Datta, 1981 and Grist, 1975). Datta (1981) reported a 10 percent loss when the crop is left in the field to dry to the level of 14-16 percent moisture before harvesting. Freshly harvested rice that ranges from 20 to 26 percent in moisture is not ideal for storage. According to Pande (1994) rice at 13 to 14 percent moisture is considered to be suitable for storage. If solar drying is not possible within 12 hours of harvest, heated air dryer should be employed to dry the rice in order to avoid spoilage through germination and overheating. A similar claim is confirmed from the research results found at the Indian Institute of Technology, Kharagpur, India, (Nath, 1983).

Storage of rice is usually equated to food security or as commodity bank for conversion to cash when the need arises. Most of the subsistence farmers in PNG store

their rice in polythene and/or Jute bags (copra bags) because these bags were cheaper and were easy to handle. However, necessary steps should be taken to plug the possible entry of vertebrate pests. Considering the need of PNG's rice farmers, a study was conducted to look into the performance of indoor-structures. Six different storage structures were used to store TCS-10 variety of paddy-rice for a period of 148 days. It was found that the moisture content of rice decreased in all the structures up to 96 days, thereafter it increased due to effect of rainfall. The germination test showed that there was no significant difference in percent germination of rice among all the storage structures. In terms of recovery of head yield and total yield, the cement-plastered and mud-plastered bins were the most suitable indoor storage structures for rice in the low-

land region of PNG. The percent broken rice was high in the metal bin because of intermittent heating and cooling of paddy rice in day and night, respectively, which made the grain more brittle, (Lindblad and Druben, 1976 and DePadua, 1974). It was anticipated that the subsistence farmers of PNG will benefit from the results of this study.

## Materials and Methods

Materials used in storage structures were locally available. Farmers used earthen jugs, woven grass baskets and plastic containers to store different kinds of seed; however, rice was different. As a result, six (6) different storage structures namely:

1. Metal bins, (T<sub>1</sub>)
2. Cement plastered bins, (T<sub>2</sub>)
3. Mud plastered bins, (T<sub>3</sub>)

**Table 1** Variation in moisture content of TCS-10 paddy-rice stored in different storage structures

Date	Storage period, day	Relative humidity, %	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	T <sub>6</sub>
26/09/05	0	70	12.00	12.00	12.00	12.00	12.03	12.00
10/10/05	15	70	11.90	11.50	11.88	11.46	11.90	11.70
25/10/05	30	65	9.90	10.35	10.47	15.51	9.21	8.90
10/11/05	46	70	9.20	9.97	10.45	11.14	9.14	9.00
15/12/05	81	75	9.20	8.40	8.65	12.10	10.40	10.50
30/12/05	96	80	9.10	8.60	8.36	12.50	11.90	11.82
01/02/06	128	80	10.00	10.20	10.60	13.00	12.50	12.30
21/02/06	148	80	10.10	10.20	10.80	13.80	14.36	13.50

**Table 2** Effect of storage period on % germination of TCS-10 variety of paddy rice

Date	Storage period, day	Relative humidity, %	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	T <sub>6</sub>
26/09/05	0	70	99	98	98	97	98	97
10/10/05	15	70	98	97	96	94	94	93
25/10/05	30	65	95	95	94	90	93	89
10/11/05	46	70	90	92	92	84	83	80
15/12/05	81	75	86	88	87	81	80	79
30/12/05	96	80	80	85	85	78	73	76
01/02/06	128	80	70	75	73	69	68	68
21/02/06	148	80	66	60	67	65	60	59

\*1. Rats had made holes in polythene bags and copra bags in Dec. 2005. Rats were also stealing rice from Bamboo strip plain bins.

2. One third of all the seeds put for germination in all the replicates had white cloudy spores and black stuff killing the small seedlings.

**Fig. 3** Germination test at the beginning of storage



**Fig. 4** Germination test after 148 days of storage



4. Bamboo strip plain bins, (T<sub>4</sub>)
5. Polythene bags, (T<sub>5</sub>), and
6. Copra bags, (T<sub>6</sub>)

were used for storing TCS-10 variety of rice for 148 days at the premises of the Department of Agriculture, University of Technology, Lae. A view of structures is shown in **Figs. 1** and **2**. The experiment started on 26 September, 2005 and moisture content, percent germination and milling quality data were collected on two week basis with some exceptions during the holidays. There were three replications.

treatments. A similar increase in moisture was recorded for plastic bags. This was because rats had made holes in the plastic bags and stealing rice by the end of December 2005. The metal bin, cement plastered and mud plastered bins were appropriate structure from the standpoint of moisture migration from the atmosphere. The moisture variation is shown in **Table 1**.

### Germination Test in the Lab

Germination tests were carried

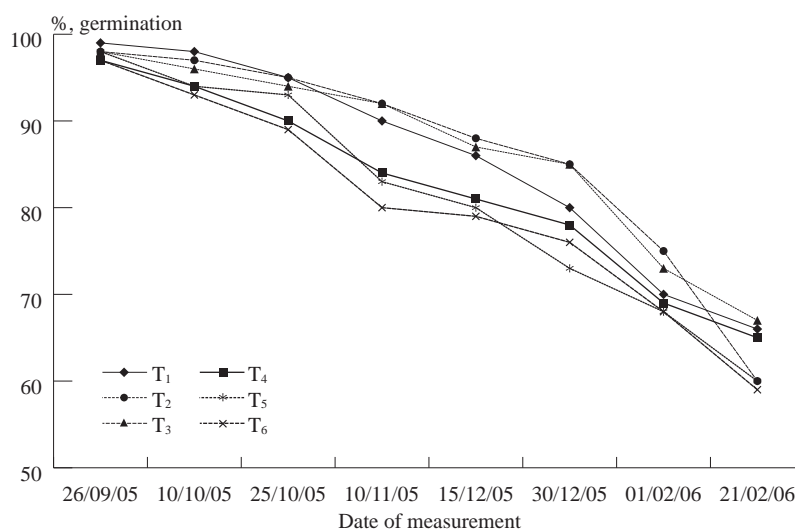
out in the days when samples were taken out to determine moisture content. A 100 seed sample was randomly taken in petridices with moist cotton and was allowed to germinate. Later the seedlings were counted for percent germination. **Figs. 3** and **4** shows the initial and final germination respectively. The detailed data regarding germination of all the treatments are presented in **Table 2**. The cement plastered and the mud-plastered bins could maintain the viability of seed at 85 % by

## Results and Discussion

### Moisture Content

The initial moisture content of rice in all types of structures was about 12 % w.b. As the time lapsed, the moisture continuously decreased in the metal bin, cement plastered, mud plastered and polythene bags up to the end of December 2005. However, there was a bit of moisture variation in bamboo strip plain bin and copra bags. This was because of plenty of aeration in both treatments resulted in more rapid increase in moisture level compared to other

**Fig. 5** Graph showing effect of storage period on germination of TCS-10 rice variety



**Table 3** Milling quality of TCS-10 variety of paddy rice stored in various storage structures

Date	Storage period, days	T <sub>1</sub>			T <sub>2</sub>			T <sub>3</sub>		
		Head yield, %	Broken, %	Total yield, %	Head yield, %	Broken, %	Total yield, %	Head yield, %	Broken, %	Total yield, %
26/09/05	0	66.10	6.54	72.64	66.10	6.54	72.60	66.10	6.54	72.64
10/10/05	15	65.00	7.90	72.90	64.20	8.50	72.70	64.30	8.00	72.30
25/10/05	30	60.20	12.75	72.95	64.14	10.50	74.64	64.00	8.30	72.30
10/11/05	46	53.85	15.63	69.48	59.64	12.20	71.84	64.68	7.00	71.68
15/12/05	81	64.30	10.46	74.76	63.30	11.00	74.34	62.30	10.80	73.10
30/12/05	96	55.35	18.45	73.80	62.74	9.30	72.02	64.50	6.80	71.30
01/02/06	128	51.16	20.09	71.25	63.30	8.60	71.90	64.00	7.40	71.40
21/02/06	148	64.00	12.00	76.00	64.00	9.00	73.00	63.00	9.35	72.35
		T <sub>4</sub>			T <sub>5</sub>			T <sub>6</sub>		
26/09/05	0	66.10	6.54	72.64	66.10	6.54	72.64	66.10	6.54	72.64
10/10/05	15	65.85	8.40	74.85	65.40	7.80	73.20	64.00	8.20	72.20
25/10/05	30	63.30	10.20	73.50	63.50	9.20	72.70	62.70	8.90	71.60
10/11/05	46	58.20	14.30	72.50	59.90	12.10	72.00	60.70	10.20	70.90
15/12/05	81	55.70	15.90	71.60	55.80	14.60	70.40	56.60	13.50	70.10
30/12/05	96	52.50	18.20	70.70	53.30	16.30	69.60	54.80	14.70	69.50
01/02/06	128	51.60	19.00	70.60	51.20	19.40	70.60	51.40	18.20	69.60
21/02/06	148	49.80	20.20	70.00	48.70	21.00	69.70	49.90	19.60	69.50

the end of 96 days of storage. These two sets of structures were the best among all the six types of storage structures. The percent germination drastically reduced to 60-65 % by the end of 148 days of storage.

### Milling Quality Test

Samples of 250 g were taken from each treatment, i.e. T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub> and T<sub>6</sub> and were milled. The facilities available at the Department of Agriculture and Livestock, (DAL) Erap, Gov't. of PNG and also at National Agricultural Research Institute, (NARI), Bubia were used.

The following relationships (Nath, 1983) were used in the analysis of the quality of milling.

$$\% \text{ Total yield} = (\text{weight of polished rice} / \text{weight of paddy rice}) \times 100$$

$$\% \text{ Polish} = (\text{weight of bran collected from the sample} / \text{weight of brown rice}) \times 100$$

$$\% \text{ Broken rice} = (\text{weight of broken rice} / \text{weight of polished rice}) \times 100$$

$$\% \text{ Total yield} - \% \text{ Broken rice} = \% \text{ Head yield}$$

The percent (%) head yield and percent (%) broken rice grain for all the treatments are shown in Table 3. The husk content was approximately between 22 to 25 percent and percent polish was between 2.65 % to 5.9 %. The variation in husk percentage was because some paddy rice seeds were hollow initially and those seeds just went as husk. The

variation in percent polish was due to damage caused by the rats. Some paddy seeds were broken into pieces and were not entirely eaten away by rodents and insects. This automatically reduced the head yield but increased the percent broken grains especially in bamboo strip, plain bin and copra bags. The plastic bags were broken into by rats that made prominent holes.

In terms of recovery of head yield and total yield, the cement plastered and mud-plastered bins were the best storage structures. Metal bins were the second best with respect to total yield. The percent broken rice was observed to be high in the metal bin as well. The reason was the intermittent heating and cooling of paddy rice in day and night which made the grain more brittle, (Linblad and Druben, 1976).

### Conclusions

1. The cement plastered and mud-plastered bins were most suited for storage of paddy rice in hot and humid lowland region of Papua New Guinea.
2. The Copra bags, Bamboo strip plain bins and Polythene bags should be used to store rice at such a place that the rodent/insects cannot reach.
3. These structures were not good for seed purposes beyond six months unless paddy rice was

treated.

Additional storage trials should be undertaken in some other locations of Papua New Guinea.

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# Threshing Unit Losses Prediction for Thai Axial Flow Rice Combine Harvester

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## Abstract

The objective of this study was to develop a prediction equation for threshing unit losses in Thai axial flow rice combine harvesters when harvesting Thai Hom Mali rice. The results of the study indicated that a prediction equation for the threshing unit losses could be modeled as a linear equation in terms of rotor tangential speed, louver inclination, grain moisture content, feed rate, grain to material other than grain ratio, and multiples of grain moisture content and grain to material other than grain ratio. The initial prediction equation was improved giving the final equation with an  $R^2 = 0.92$ . The final equation had an average error of 0.10 % of loss for value error.

## Introduction

Thai Hom Mali rice is a high quality and very important rice to the economy of Thailand. It covers approximately 3.2 million hectares (ha) of cultivated area and yields about 6.5 million metric tons of rice grain for an average yield of 2.03 metric tons/ha (DOA, 2003). Harvesting rice is a very important process which affects the quality and quantity of the rice. Rice combine harvesters are playing a more important role in harvesting and are widely used, especially in the

central part of the country. It is estimated that there are about 4,000 rice combine harvesters being used. Almost all of them are Thai-designed rice combine harvesters and all of them have an axial flow threshing unit as show in **Fig. 1**. The number of harvesters tends to increase as the rice crop spreads throughout Thailand (Chinsuwan et al., 2003b).

The axial flow threshing unit threshes and separates the rice. The input plant material is threshed and moved around the concave and given an axial motion by louvers (Khan, 1986) as show in **Fig. 2**. Overall threshing unit losses can be a significant problem for axial flow rice combine harvesters (Chinsuwan et al., 2003a and Chinsuwan et al., 2003b). These losses are affected by highly fluctuating factors related to different crop conditions, machine operation, and machine adjustments. For machine operation, the operator of the rice combine harvester usually readjusts the machine and/or uses the highest forward speed (Chinsuwan et al., 2003b). The operator can cause greater losses without realizing it following these changes.

Chinsuwan et al. (2003a) studied the effects of rotor tangential speed and feed rate on threshing unit losses and rice grain damage. The data obtained showed that the threshing unit losses decreased and the damage increased when the rotor tangential speed was increased.

Chinsuwan et al. (1997) reported that higher levels of grain moisture content resulted in more difficulty in threshing and grain separation in the threshing unit than lower levels of grain moisture content.

Andrews et al. (1993) studied the effects of combine operating parameters on harvest loss in rice and reported that feed rate, material other than grain to grain ratio, moisture content, rotor speed, and concave clearance affect threshing unit losses. Gummert et al. (1992) reported that rotor speed, feed rate, and louver inclination affect threshing unit losses and that the rotor speed affects grain damage.

Predicting threshing unit losses when combine harvesting is to be done at different field and crop conditions and at different machine adjustments can be useful to the operator in order to set the combine for proper operation. The objective of this study was to develop prediction equations for threshing unit losses in axial flow rice combine harvesters when harvesting Thai Hom Mali

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rice, the most popular and most widely cultivated variety.

## Methodology

### Development of Threshing Unit Loss Prediction Equations

#### Equipment:

The equipment used in this study was a Thai axial flow rice combine harvester that had a threshing rotor length of 1.92 m with a diameter (to peg tip) of 0.68 m. Each peg was 11 mm in diameter and 82 mm long and the space between pegs was 70 mm. The concave rods were 7 mm in diameter with a 17 mm clearance between each concave rod. There were 5 louvers and the combine harvester cutting width was 3 m. The engine power was 194 kW (260 hp).

#### Experimental Factors:

There were five independent variables considered in developing the prediction equations for threshing unit losses (TL): rotor tangential speed (RS), louver inclination (LI), grain moisture content (MC), feed rate (FR), and grain to material other than grain ratio (GM). For the testing, the RS were 15.78, 16.50, 17.22, 17.93, 18.65, and 19.37 m/s. The LI (Fig. 3) settings were 64, 66, 68, 70, 72, and 74 degrees and MC depended on crop conditions during testing. The FR was grain and material other than grain through the threshing unit and varied with 3 forward speeds of 3, 4, and 5 km/h; and GM varied with cutting height set at 3 levels, low, medium, and high. The variety used in this study

was Thai Hom Mali rice.

To help in managing these tests the five variables were simplified by setting the LI at a fixed value for each testing day during the testing period of 10 days. The MC depended on the conditions of plot of the day and there were three plots

for each day of testing while the RS, the forward speed, and the cutting height were varied alternately each day. FR depended on the forward speed, the cutting height, cutting width, and crop conditions and GM depended on the cutting height, and crop conditions. The average data

**Table 1** Average test data for development of threshing unit loss prediction equations\*

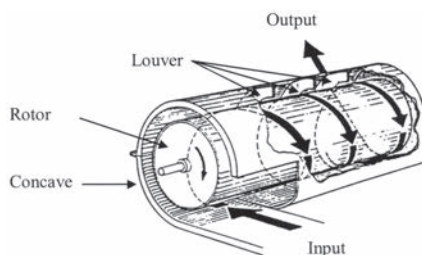
LI, degrees	MC <sub>g</sub> , % w.b.	RS, m/s	FR, t/h	GM	TL, %	HL, kg/ha**
68	27.47	15.78	7.98	0.83	0.81	119.0
	26.95	17.22	9.10	1.05	0.97	143.4
	27.79	18.65	10.81	1.38	1.06	134.5
72	26.22	16.50	11.58	0.78	1.02	103.3
	26.69	17.93	9.01	1.04	0.44	126.5
	26.63	19.37	7.60	1.12	0.38	147.9
70	25.48	15.78	8.71	1.23	1.07	86.9
	24.89	17.22	6.14	1.53	0.63	99.3
	24.94	18.65	10.09	0.95	0.51	124.6
64	24.14	16.50	10.46	0.97	1.03	109.5
	24.38	17.93	11.97	1.16	0.97	115.8
	24.41	19.37	9.68	0.81	0.73	216.1
74	24.99	15.78	7.06	1.40	0.47	96.4
	24.61	17.22	10.61	1.04	0.38	138.9
	24.04	18.65	5.87	1.32	0.27	240.6
68	25.07	16.50	7.13	1.06	0.98	133.9
	25.67	17.93	12.23	0.75	0.56	166.9
	26.22	19.37	13.27	1.00	0.49	175.1
66	24.02	15.78	7.00	0.86	0.83	100.7
	23.57	17.22	8.84	0.72	0.65	135.7
	23.30	18.65	10.17	0.87	0.52	156.1
70	22.47	16.50	5.80	0.95	0.41	92.9
	22.65	17.93	8.18	1.19	0.31	160.7
	23.06	19.37	11.30	0.86	0.42	152.1
66	20.78	15.78	6.09	0.79	0.78	177.6
	19.94	17.22	7.53	0.42	0.54	165.9
	20.66	18.65	6.12	0.58	0.39	222.7
72	17.80	16.50	12.75	0.30	0.75	205.9
	16.94	17.93	6.40	0.45	0.42	331.9
	17.31	19.37	7.39	0.47	0.36	464.7

\* 3 replications, \*\* 14 % w.b.

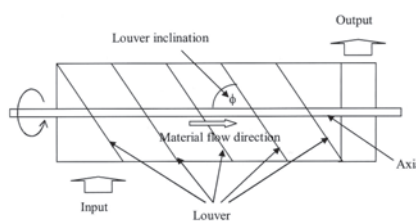
**Fig. 1** Thai-designed rice combine harvester during field operation



**Fig. 2** Principle of axial flow thresher operation (Khan, 1986)



**Fig. 3** Louver inclination, top view





are shown in **Table 1** along with the total machine harvest loss (HL).

**Measurements:**

During the testing, all throughput material of the threshing unit was collected in nets. The material other than grain was then separated in order to collect grain still attached to the paddy ears. Other loose grain was threshing unit loss. Percentage of the grain to total yield was percentage of threshing unit losses.

**Equation Development:**

LI, MC, RS, FR, and GM values in **Table 1** were used to develop a prediction equation for the TL for the combine harvester by applying general equations for a quadratic response surface, as show in Eq.1 (Berger and Maurer, 2002). A regression equation was developed and any equation term that had a very small effect as an independent variable was eliminated. Next, the regression equation was reformulated without the eliminated term. Thus, the term in the regression equation that had the least effect on the dependent variable was eliminated and a new regression equation was produced as long as the validity value of the final prediction equation terms was not lower than 95 %.

$$Y = A_0 + \sum_{(j=1,k)} A_j X_j + \sum_{(j=1,k)} A_{ij} X_j^2 + \sum_{(j=1,k)} \sum_{(j=1,k)} A_{ij} X_i X_j, \dots\dots\dots(1)$$

where

- Y = dependent variable
- X<sub>i</sub>, X<sub>j</sub> = independent variable
- A<sub>0</sub>, A<sub>j</sub>, A<sub>ij</sub> = constant

**Equation Improvement**

Determining the TL for Thai Hom Mali rice from 13 different Thai axial flow rice combine harvesters led to improvement of the prediction equation. The field data values of RS, LI, MC, FR, and GM, are shown in **Table 2** along with the HL. The actual TL were compared to the predicted loss. For prediction equation improvement, the field data for the 13 machines were incorporated into a new regression equation.

**Equation Validation**

The prediction equation was validated by using field data from 20 Thai axial flow rice combine harvesters. The field data values of RS, LI, MC, FR, and GM, are show in **Table 3** along with the HL. The actual TL were compared to the predicted loss and value error (Eq. 2) and percentage error (Eq. 3) were used to compare.

$$\text{Value error} = |TL_f - TL_p| \dots\dots\dots(2)$$

$$\text{Percentage error} = |TL_f - TL_p| \times 100 / TL_f \dots\dots\dots(3)$$

where

- TL<sub>f</sub> = field threshing unit losses
- TL<sub>p</sub> = prediction threshing unit losses

**Results and Discussion**

**Threshing Unit Loss Prediction Equations**

The RS, LI, MC, FR, GM, and multiples of MC and GM were linearly related to the TL as shown in Eq. 4. This equation had a prediction proficiency of R<sup>2</sup> = 0.76.

$$TL = 7.234 - 0.0471(LI) - 0.0724(MC) - 0.117(RS) + 0.029(FR) - 2.983(GM) + 0.13(MC \times GM) \dots\dots\dots(4)$$

**Equation Improvement**

Eq. 4 was used to predict TL using specific data from 13 combine harvesters as listed in **Table 2**. The predicted TL errors ranged from 0.07 to 0.40 % of loss with an average of 0.20 % of loss for value error or 6.78 % to 35.33 % with an average of 18.26 % for percentage error.

The additional data from the comparison of losses were used to produce another regression equation as an improvement over Eq. 4 and is given by Eq. 5. This equation has R<sup>2</sup> = 0.92.

$$TL = 8.31 - 0.0621(LI) - 0.0488$$

**Table 2** Average test data for 13 different combine harvesters\*

Field test							Prediction	Errors	
LI, degrees	MC, % w.b.	RS, m/s	FR, t/h	GM	TL <sub>f</sub> , %	HL, kg/ha**	TL <sub>p</sub> , %	Value, %	Percentage, %
69.44	28.19	17.87	8.68	0.85	0.73	40.1	0.66	0.07	9.43
65.56	25.21	15.08	6.12	0.98	1.19	51.6	1.02	0.17	14.16
68.51	25.89	16.60	7.86	0.81	0.62	78.0	0.73	0.11	17.34
61.92	25.69	15.26	9.24	0.54	1.53	87.2	1.13	0.40	26.11
68.51	23.40	15.21	7.89	0.82	0.87	59.5	0.81	0.06	6.78
61.77	22.72	16.76	9.16	0.78	1.11	66.1	0.96	0.15	13.35
61.57	21.61	18.81	12.03	0.41	1.15	66.1	0.85	0.30	26.63
63.50	23.55	14.59	5.19	0.78	1.19	63.1	1.04	0.15	12.71
60.25	28.44	14.97	5.65	0.81	1.48	92.4	1.32	0.16	10.08
67.88	25.89	15.56	12.13	0.71	1.28	87.4	0.97	0.31	24.59
65.33	16.26	15.73	10.07	0.38	1.37	92.3	1.11	0.26	19.70
66.70	16.21	16.38	5.97	0.73	0.82	95.1	0.54	0.28	35.33
69.74	16.24	15.55	6.90	0.69	0.70	62.6	0.56	0.14	21.18
							Average	0.20	18.26

\* 3 relocations, \*\* 14 % w.b.

$$(MC) - 0.152(RS) + 0.0578(FR) - 2.069(GM) + 0.0834(MC \times GM) \dots\dots\dots(5)$$

**Equation Validation**

Eq. 5 was validated to predict TL using data from 20 combine harvesters as listed in **Table 3**. The predicted TL errors ranged from 0.01 to 0.33 % of loss with an average of 0.10 % of loss for value error or 1.00 % to 20.51 % with an average of 8.45 % for percentage error.

Eq. 5 allowed the study of the effects of the system parameters on predicted losses. **Fig. 4** shows the results of variable RS and LI on TL. The figure shows that TL decrease as RS or LI increase. The increased RS caused greater forces in threshing and the increased centrifugal force caused more threshed grain to go through the concave and for decreased losses. In addition, increased LI caused decreased axial traveling speed of material in the threshing unit. This affected the length of time for the threshing and grain

separation process, which had a direct effect on TL (Gummert et al., 1992).

The effect of RS and MC on TL indicated that the losses were reduced when RS was increased or when MC was decreased during the combine harvesting process as shown in **Fig. 5**. Higher levels of MC result in more difficulty in threshing and grain separation in threshing (Chinsuwan et al., 1997).

**Fig. 6** shows the results of how RS and FR affect the TL. The figure shows that when FR decreases or when RS increases the losses are reduced. FR affects the losses because increasing the FR is an act of adding more material into the threshing unit per unit time. This caused the threshing unit to be unable to thresh and separate grain in an efficient manner resulting in more losses in the threshing unit (Chinsuwan et al., 2003a and Gummert et al., 1992).

The effects of RS and GM on the TL are shown in **Fig. 7**. The figure shows that increasing RS or GM

caused lower losses in the threshing unit. GM affects the losses because increased GM is an act of reducing material other than grain in the threshing unit. This causes the threshing unit to be able to thresh and separate grain in a more efficient manner resulting in smaller losses in the threshing unit.

From the prediction equation, if the threshing unit losses when combine harvesting Thai Hom Mali rice is to be no more than 1 %, the RS should not be lower than 17 m/s with a FR not higher than 10 t/h. This correlates with the study of Chinsuwan et al. (2003b) when the MC is no more than 26 % wb, as well as correlating with the study of Chinsuwan et al. (1997). The LI should not be less than 66 degrees, and the GM no more than 0.75.

**Conclusions**

The prediction of threshing unit losses in Thai axial flow rice com-

**Table 3** Average validation data for 20 combine harvesters\*

Company		Field test							Prediction	Errors	
Brand	No.	LI, degrees	MC, % w.b.	RS, m/s	FR, t/h	GM	TL <sub>f</sub> , %	HL, kg/ha**	TL <sub>p</sub> , %	Value, %	Percentage, %
A	1	62.30	21.71	16.68	10.47	0.61	1.23	61.3	1.29	0.06	4.88
	2	61.14	25.06	16.98	24.01	0.32	2.28	109.7	2.10	0.18	7.46
B	1	68.51	24.98	16.38	11.94	0.35	1.08	69.3	1.04	0.04	3.70
	2	61.14	29.78	15.83	11.21	0.31	1.39	56.0	1.43	0.04	2.88
C	1	62.30	24.82	14.71	10.91	0.52	1.77	76.5	1.62	0.15	8.47
	2	61.14	17.58	15.64	12.03	0.44	1.82	107.2	1.71	0.11	6.04
D	1	63.80	28.31	18.55	11.10	0.50	1.17	64.9	0.93	0.24	20.51
	2	61.03	24.56	20.11	11.94	0.32	0.85	54.7	0.95	0.10	11.76
	3	63.07	27.87	19.67	17.65	0.43	1.32	58.9	1.17	0.15	11.36
E	1	68.51	27.07	18.36	7.52	0.60	0.53	43.1	0.49	0.04	7.55
	2	72.44	26.30	16.42	16.03	0.44	1.00	65.4	1.01	0.01	1.00
	3	71.25	26.14	17.24	9.84	0.45	0.63	39.7	0.61	0.02	3.17
F	1	60.65	22.84	15.56	7.14	0.61	1.46	69.2	1.38	0.08	6.16
	2	68.51	17.63	16.61	12.00	0.55	0.89	55.4	1.04	0.15	15.73
G	1	68.51	29.16	19.21	10.31	0.61	0.52	39.2	0.53	0.01	1.92
	2	68.51	27.08	17.13	12.13	0.51	1.10	49.9	0.93	0.17	15.45
H	1	59.44	27.08	18.21	5.45	0.67	0.86	90.0	0.97	0.11	12.79
I	1	72.90	22.95	18.23	14.40	0.40	0.60	66.6	0.66	0.06	10.00
J	1	68.51	29.76	15.69	20.04	0.31	1.53	62.7	1.50	0.03	1.96
K	1	59.44	28.44	15.21	11.48	0.42	2.04	102.1	1.71	0.33	16.18
									Average	0.10	8.45

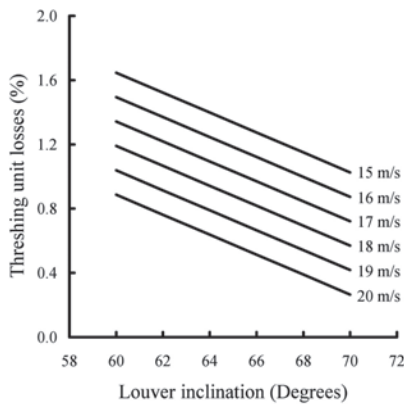
\* 3 relocations, \*\* 14 % w.b.

bine harvesters for Thai Hom Mali rice was modeled as a linear equation in terms of RS, LI, MC FR, GM and multiples of MC and GM. The initial prediction equation was improved by using the field data from 13 different machines giving the final equation with an  $R^2 = 0.92$ . The final equation had an average error of 0.10 % of loss for value error.

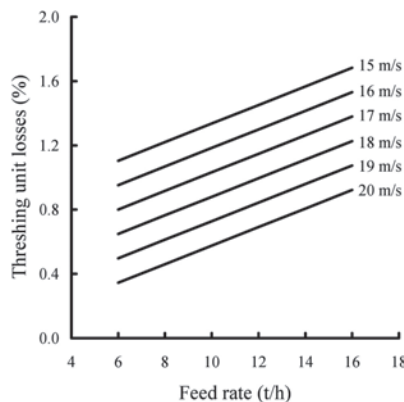
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**Fig. 4** Effect of louver inclination on threshing unit loss at different rotor speeds. Loss rates were predicted with grain moisture content, feed rate, and grain to material other than grain ratio held constant at 23 % w.b., 10 t/h, and 0.75, respectively



**Fig. 6** Effect of feed rate on threshing unit loss at different rotor speed. Loss rates were predicted with louver inclination, grain moisture content, and grain to material other than grain ratio held constant at 68 degrees, 23 % w.b., and 0.75, respectively

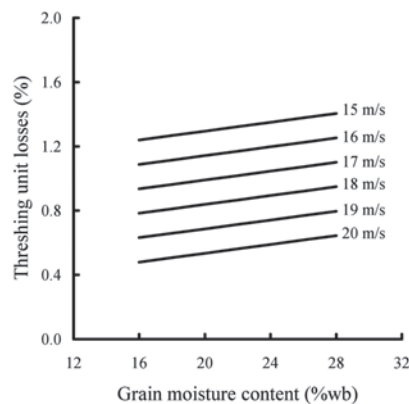


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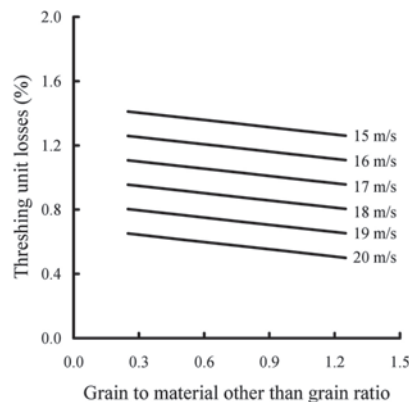
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**Fig. 5** Effect of grain moisture contain on threshing unit loss at different rotor speeds. Loss rates were predicted with louver inclination, feed rate, and grain to material other than grain ratio held constant at 68 degrees, 10 t/h, and 0.75, respectively



**Fig. 7** Effect of grain to material other than grain ratio on threshing unit loss at different rotor speeds. Loss rates were predicted with louver inclination, grain moisture contain, and feed rate held constant at 68 degrees, 23 % w.b., and 10 t/h, respectively



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# Development and Performance Evaluation of Prototype Double Roller Gin

by



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## Abstract

Double roller gins are commonly used in India for ginning seed cotton. International Textile Manufacturers Federation's survey 2005 reported that degree of grease and oil contamination in cotton lint is serious in India. The source of this contamination is the gearbox (power transmission system) of the double roller gin as it is filled with grease/oil measuring about 20 kg. Further, chrome leather washers are used for manufacturing of rollers. These are not operator and eco-friendly due to pollution. A prototype double roller gin has been designed and developed with a new power transmission system and alternate roller materials (viz. canvas and Nyla-thane) were tested. Performance evaluation studies have revealed that the newly designed prototype double roller gin requires minimum grease and the oil and roller material tested work satisfactorily. High Volume Instrument's showed that quality of lint is at par with existing double roller gins with no prospect of oil and grease contamination. The developed machine

is useful for cotton breeders, seed processing industries, ginneries and research institutes and will be the basis for modified double design of a commercial size roller gin.

## Introduction

India ranks first in area under cotton cultivation and is third largest producer of cotton fibre in the world with 4.148 million tonnes on 9.0 million hectares during 2005-06 (ICAC, 2006). Ginning is the process by which seed cotton is separated into lint (fibres) and seed and the machine used for separation is called a gin. Thus, ginning is the first engineering activity that cotton undergoes on its way from cotton field to textile mills (Patil et al., 2006). There are mainly two types of gins; roller gins and saw gins. In India, mostly roller gins are used for commercial ginning. About 50,000 double roller (DR) gins were operating in India for ginning and producing 3.32 million tonnes of fibre in 2005-2006 (80 % of total cotton lint production).

The process of ginning cotton is

a complex phenomenon. In a double roller gin, two spirally grooved leather rollers are pressed against a fixed, stationary knife with the help of adjustable dead loads, and rotate in opposite directions at a definite speed. The three beater arms are inserted in the beater shaft and two knives are fixed to the beater arms with proper alignment. This is known as the beater or moving knife, which oscillates by means of a crank or eccentric shaft, close to the leather roller. When the seed cotton is fed to the machine in action, fibres adhere to the rough surface of the roller and are carried in between the fixed knife and the roller such that the fibres are partially gripped between them. The oscillating knives beat the seeds from top and separate the fibres that are gripped from the seed end. This process is repeated a number of times and the fibres are separated from the

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seeds, carried forward on the roller and dropped out of the machine. The ginned seeds drop down through the slots provided on the seed grid, which is part of the beater assembly that also oscillates along with the moving knife.

A planetary gear train is used in existing DR gins for power transmission and is complicated and requires greasing frequently. The gear box is filled with grease up to 20 % of its capacity and weighing about 20 kg as shown in **Fig. 1**. About 500 grams of grease must be added weekly to maintain the proper level in the gearbox (Patil et al., 2003). Yearly oil and grease consumption by DR gins is estimated to be 1500 tonnes, costing about Indian Rs. 120 to 150 million (US \$ 2.6 to 3.2 million). During the running of the DR gin, there is a leakage of the grease from the gearbox, which subsequently falls on the floor surface of the gin house and damages the cotton lint quality. The roller of the DR gins is made from chrome leather washers, which are made by stitching leather pieces. The wear and tear is very high. Life of the

roller is 1,200 to 1,250 hours of ginning operation. Microdust generated due to wear of roller is not operator and eco-friendly (Iyer, 2004 and Patil et al., 2003). Besides this, in the rainy season leather has a tendency to absorb water and swell, which reduces the life of the material. Gillum (1974), tested different roller material and found that fabric and rubber packing type material is superior to all types of material tested. Some other alternate and appropriate covering material for the roller needs to be tested. Hence this study is undertaken with the following objectives:

1. To design an improved power transmission system that requires minimal grease for lubrication.
2. To design and develop a prototype double roller gin with alternate roller material.
3. To evaluate a prototype double roller gin that incorporates the improvements.

### Necessity of Design of Prototype DR Gin

Before developing a full size com-

mercial DR gin, it was necessary to develop a prototype model of DR gin to study the performance of the new power transmission system and new roller material. Also, the performance evaluation of the newly developed prototype machine for ginning cotton could be studied. Advantages of developing a prototype model of the DR gin included cost required for fabrication of the prototype model. Some minor design modifications required could be incorporated quickly and economically.

## Materials and Methods

### Principle of Operation of Prototype Double Roller Gin

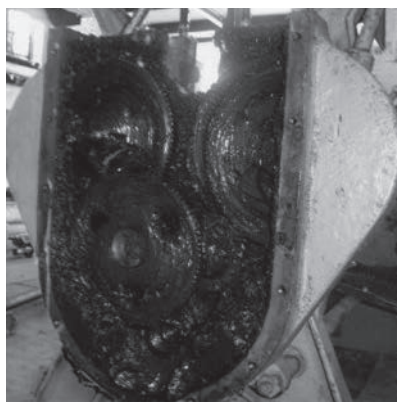
The prototype double roller gin was designed to work on the principle of Ma-Carthy's gin. The principle of operation of the prototype DR gin is shown in **Fig. 2**.

Chrome leather rollers, fixed knives and moving knives were the main components of the gin. Spirally grooved rollers were pressed against fixed knives and rotated at a definite speed. Each moving knife reciprocated by means of a crank or eccentric shaft close to the leather roller. When seed cotton was fed to the machine, fibres adhered to the rough surface of the roller and were carried between the fixed knife and the roller such that the fibres were partially gripped between them. The moving knife beat the seeds and separated the fibres that were gripped from the seed end. This process was repeated a number of times and, due to the 'push and pull' action, the fibres were separated from the seeds. The separated fibres were carried forward on the roller and passed upwardly and dropped out of the machine. The ginned seeds dropped down through the grid slots provided.

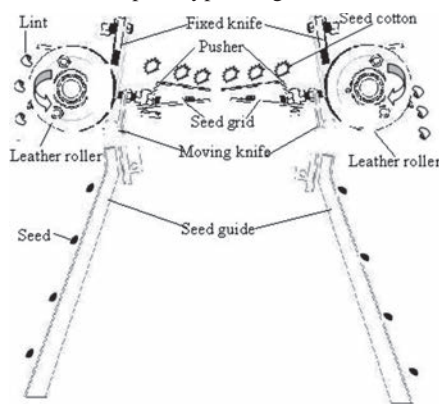
To understand the actual ginning process, it is necessary to describe the gin cycle.

Gin cycle, the time taken by the reciprocating knife to complete one

**Fig. 1** Grease application in existing DR gin



**Fig. 2** Principle of operation of prototype DR gin



**Table 1** Ginning rate of prototype double roller gin and commercially available DR gin

Particular	Roller length, mm	Roller diameter, mm	Ginning percentage, %			Ginning rate, g m <sup>-1</sup> s <sup>-1</sup>		
			Cotton A	Cotton B	Cotton C	Cotton A	Cotton B	Cotton C
Prototype DR gin (Newly developed)	254	125	36	36	31.9	4.7	4.4	4.8
DR gin (Commercially available)	1,360	170	36	35.9	32	11.2	9.6	12.4

period (full cycle), can be taken as the time period represented by T in Fig. 3. The figure shows four relative positions (A-B-C-D) of the reciprocating knife with reference to the roller and describing one cycle.

### Design of Prototype Double Roller Gin

Power of electric motor = 1.5 hp  
 Speed of crankshaft = N<sub>2</sub>  
 Speed of the motor = N<sub>1</sub> = 1440 rpm  
 $N_1/N_2 = D_1/D_2: 1440/N_2 = 147/33$   
 Diameter of motor pulley = D<sub>1</sub> = 33 mm  
 So, N<sub>2</sub> = 320 RPM  
 Diameter of crank shaft pulley = D<sub>2</sub> = 147 mm  
 In the first stage, speed reduction ratio is 1: 4.5 that is achieved with the help of a v-belt drive. In the second stage the reduction of speed is carried out in 1:3 ratio and achieved with the help of a chain drive.  
 No. of teeth on crankshaft sprocket = T<sub>2</sub> = 15  
 Speed of roller = N<sub>3</sub>  
 No. of teeth on roller sprocket = T<sub>3</sub> = 30  
 $N_2/N_3 = T_3/T_2: 320/N_3 = 30/15$   
 Speed of crankshaft = N<sub>2</sub> = 320 RPM  
 So, N<sub>3</sub> = 160 RPM  
 The length and diameter of the

roller is 254 mm and 125 mm, respectively. The roller rotates at the speed of 160 RPM with a surface speed of about 105 cm/s. In existing DR gins, surface speed of the roller is 95 to 105 cm/s.

### Constructional Features of Prototype Double Roller Gin

The essential machine parts of

prototype double roller gin are:

1. Main frame of machine
  2. A pair of chrome leather roller
  3. A pair of fixed knives
  4. Power transmission system
  5. A pair of reciprocating knives also called beater
  6. Eccentric shaft
- Side, front and top views of the

Fig. 3 Gin cycle of a prototype DR gin

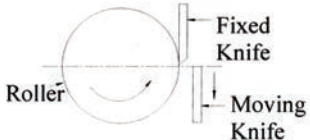
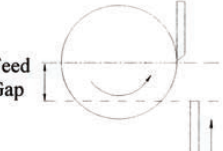


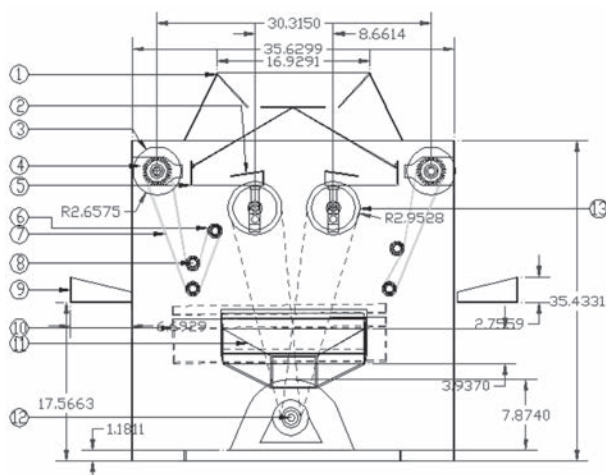
Relative positions of fixed and moving knife with reference to roller	Description of gin cycle
(A) 	<ol style="list-style-type: none"> <li>1. The overlap is zero</li> <li>2. The moving knife is moving down</li> <li>3. Feeding is about to start</li> <li>4. Time T = 0</li> </ol>
(B) 	<ol style="list-style-type: none"> <li>1. The moving knife is farthest</li> <li>2. The feeding gap is maximum</li> <li>3. Moving knife reverses its direction</li> <li>4. Feeding time lapsed T<sub>f</sub>/2</li> <li>5. Time t = T<sub>f</sub>/2</li> </ol>
(C) 	<ol style="list-style-type: none"> <li>1. The overlap once again becomes zero</li> <li>2. Feeding ends</li> <li>3. Total feeding time lapsed is T<sub>f</sub></li> <li>4. Ginning begins</li> <li>5. Time lapsed t = T<sub>f</sub></li> </ol>
(D) 	<ol style="list-style-type: none"> <li>1. The overlap is maximum</li> <li>2. Ginning ends</li> <li>3. Total ginning time lapsed is T<sub>g</sub>/2</li> <li>4. Moving knife is about to reverse its direction</li> <li>5. Total time T = T<sub>f</sub> + T<sub>g</sub>/2</li> <li>6. Idle time to complete the cycle = T<sub>g</sub>/2</li> </ol>

Fig. 4 Side view of prototype double roller gin



- 1: Feed hopper, 2: Moving knife, 3: Leather roller, 4: Roller sprocket, 5: Fixed knife, 6: Sprocket, 7: Chain, 8: Idler sprocket, 9: Lint collection tray, 10: Seed tray, 11: Seed outlet, 12: Motor, 13: Pulley

Fig. 5 Front view of prototype double roller gin

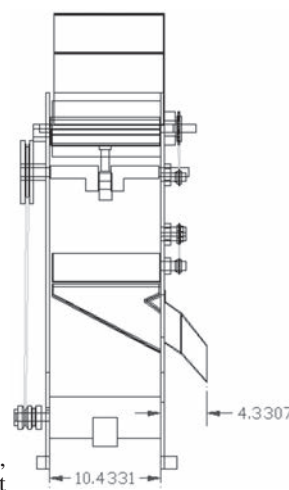
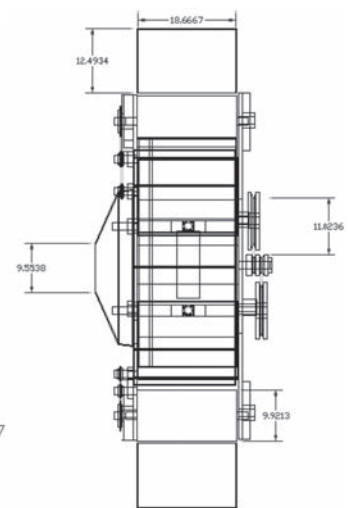


Fig. 6 Top view of prototype double roller gin



All dimensions are in mm

prototype DR gin are shown in **Figs. 4, 5 and 6**, respectively. The main frame of the machine is fabricated out of cold rolled sheet metal. Both the moving and fixed knives are made of EN-8 alloyed steel. The roller is made of chrome composite leather washers. A single-phase, 1.5 hp motor is used to provide power which is essential to drive the rollers and moving knives. The eccentric shaft is fixed in between the two metal sheets, which is driven by a belt and pulley mechanism from the motor. The power to drive the rollers is supplied by chain and sprocket mechanism driven by the eccentric shaft. The eccentric shaft drives the moving knife and the pusher for both the sides, which helps to feed the seed cotton at the ginning point. The two screws are provided to adjust height of the fixed knife in order to adjust the overlap between the fixed knife and moving knife. Slots are provided on bearing housings of the roller to adjust the pressure between the fixed knife and roller. The mechanism is provided to adjust the gap between the fixed and moving knife.

The length and diameter of the roller is 254 mm and 125 mm, respectively, and rotates at a speed of 160 rpm. The moving knife reciprocates at a speed of 320 strokes per minute. The grooves on the surface of the roller are 25 mm apart and the width and depth are 2 mm. The wooden flat is placed on the front side of the roller to avoid the backlash. The lint collection tray is provided just below the roller and the seed collection tray is beneath the seed grid. A small rectangular hopper is used to feed the cotton.

The belt pulley and chain sprocket have safety guards and handles provided on both sides of the machine for ease in handling. The schematic diagram of the gin is shown in **Figs. 7 and 8**.

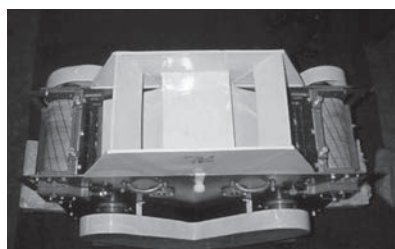
## Results and Discussion

### Performance Evaluation of Prototype Double Roller Gin

The developed prototype double roller gin was tested to evaluate its performance in terms of ginning rate, ginning percentage and fibre quality parameters. The varieties selected for testing performance of the gin were: Cotton A, Cotton B and Cotton C. Cotton A and B are long staple (30 mm) varieties and Cotton C is a short staple (24 mm) variety. A 2 kg seed cotton sample with a moisture content of 7 % was ginned on the developed prototype double roller gin. The ginning rate and ginning percentage (GP) was calculated for each cotton type. The GP of given sample was calculated by formula:

$$\text{Ginning Percentage (\%)} = \left( \frac{\text{Weight of lint}}{\text{Weight of seed cotton}} \right) \times 100$$

**Fig. 7** Top view of the machine showing both the leather rollers, fixed knife, feed hopper and power transmission system of prototype DR gin



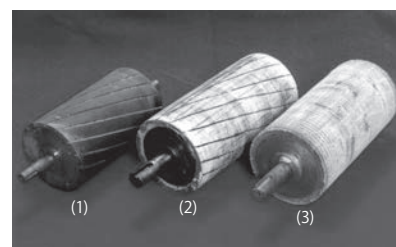
The ginning rate in grams of lint obtained per second per metre of roller length ( $\text{g m}^{-1}\text{s}^{-1}$ ) and GP of three cottons, when ginned using the prototype double roller gin and commercially available DR gin, are presented in **Table 1**.

Fibre properties, viz. 2.5 % span length (SL), uniformity ratio (UR), fineness (micronaire, mic) and tenacity, of lint obtained from the prototype double roller gin and commercially available DR gin were measured using High Volume Instrument (HVI)-900 of Uster Technologies (USA) and are presented in **Table 2**. The fibre properties remained practically the same whether ginned with the prototype double

**Fig. 8** Developed prototype double roller gin in operation



**Fig. 9** (1) Nyla-thane, (2) leather, (3) canvas rollers



**Table 2** Fibre properties of lint obtained by ginning on prototype double roller gin and commercially available DR gin

Cotton	Prototype double roller gin (Newly developed)				Double roller gin			
	2.5 % SL, mm	UR, %	Mic	Tenacity, g/tex.	2.5 % SL, mm	UR, %	Mic	Tenacity, g/tex.
A	30.0	49	4.4	22.9	29.7	48	4.2	22.9
B	30.5	51	4.0	22.7	30.8	47	4.0	24.3
C	24.1	51	5.6	16.0	24.0	51	5.6	16.0

roller gin or the commercially available DR gin. The statistical analysis showed that the variance due to gin type was not significant.

### Roller Materials

The roller plays very important role in ginning. Three roller materials were used, namely chrome composite leather roller, Nyla-thane and canvas as shown in **Fig. 9**. Properties of the Nyla-thane roller are given in **Table 3**.

Temperature characteristics of the Nyla-thane, leather and canvas rollers during ginning for two hours continuously are presented in **Table 4**. Atmospheric dry bulb temperature and relative humidity during conduct of experimentation were 34 °C and 41 %, respectively.

The cost of the prototype double roller gin was about US \$870 (about Indian Rupees 40,000). The prototype double roller gin will have application in various cotton research institutes, agricultural universities, cotton markets, ginneries and seed industries for ginning the medium size cotton samples.

## Conclusions

- A prototype double roller gin was designed and developed. Quantity of grease and oil requirement for the newly designed machine was minimal. The gear train was totally replaced by v-belt and chain sprocket combination.
- In addition to a leather roller, Nyla-thane and canvas roller materials worked satisfactorily in this gin.
- The machine was simple and robust in construction.
- Quality evaluation studies indicated that quality of lint was not affected.
- The prototype DR gin will have application in various cotton research institutes, agricultural universities, cotton markets, ginneries and seed industries for ginning.
- The design improvements incorporated in the prototype DR gin are encouraging, therefore, a scaled-up model having roller length equivalent to one with a

commercial DR gin (i.e. 1,360 mm) can be designed and developed. Further, the performance must to be evaluated by carrying out the extensive experimentation.

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**Table 3** Properties of Nyla thane

Properties	Test method	Unit	Value NT 90
Shore hardness	ASTM D2240	Scale A	90 A
Tensile strength	DIN 53455	kg/cm <sup>2</sup>	315
Elongation	DIN 53455	%	450
Specific gravity (25 °C)	ASTM D792	-	1.10
NBS abrasion index	ASTM D1830	%	1.75
Maximum service temperature			
Continuous		°C	85
Intermittent		°C	100-110
At low temperature		°C	-40
Compression set	DIN 53517	%	27
Tear strength (After 22 hrs at 70 °C)	ASTM D470	kg/cm <sup>2</sup>	14

**Table 4** Temperature characteristics of the Nyla-thane, leather and canvas rollers

Time (h: min)	Temperature of the roller, °C		
	Nyla-thane roller	Chrome leather roller	Canvas roller
Start	28	28	27
0:15	36	32	33
0:30	40	36	34
1:00	40	36	35
1:30	41	36	35
2:00	40	36	35



# Impact of Tillage and Nutrient Management in Maize-Wheat Crop Rotation Under Dryland Cultivation

by

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## Abstract

Tillage is a major farm operation that consumes time, energy and expense. Dryland cultivation practices need to minimize cost of production in all crops. An experiment has been conducted on two tillage systems; (1) conventional and (2) reduced tillage, to save energy in production of maize and wheat. Three tillage treatments in combination with three fertilizer treatments were used. The highest yield of maize was 20.50 q/ha with conventional tillage + interculture. The next highest yield for maize was 20.16 q/ha with 50 % conventional tillage + weedicide + interculture. The highest yield of wheat was 29.33 q/ha with 50 % conventional tillage + weedicide + interculture. The next highest yield of wheat was 27.87 q/ha with conventional tillage + interculture. The fertilizer treatment showed the highest average grain yield of maize of 21.90 q/ha with 100 % N with inorganic fertilizer. The next highest fertilized treatment with maize was with

50 % N through organic + 50 % N through inorganic fertilizers for a yield of 19.85 q/ha. A similar trend was found for wheat with the highest average grain yield of 29.00 q/ha with 100 % N through inorganic fertilizer. The next highest fertilized treatment with wheat was with 50% N through organic + 50% N through inorganic fertilizers with a grain yield of 28.25 q/ha. The operational energy and cost of operation were higher in the conventional tillage system (5,013.8 MJ, Rs.10,574 and 2,907.53 MJ, Rs.11,347.33) than in reduce tillage (3,625.39 MJ, Rs.9,750 and 2,227.20 MJ, Rs.10,335.30) and the benefit cost ratio ranged from 1.52: 1 to 0.36: 1 and 1.08: 1 to 1.41: 1 in production of maize and wheat, respectively.

## Introduction

Maize (*Zea Mays*) and wheat (*Triticum aestivum*) are grown in an area of about 6.59 M ha, in Rajasthan, U.P., M.P., Bihar, Karnataka, Andhra Pradesh, Gujarat, J&K, Himachal

Pradesh and Maharashtra that are the major states growing these crops. The production and quality of grain, especially maize, is governed by its genetic purity, germ inability, vigor, storability without loss of germination and foreign material. Maize is a staple food crop in the dryland area of Jammu division of J&K state. Maize and wheat have special importance in the hilly and sub mountainous region of Jammu division where it forms the staple diet of the people. It has the highest area under cultivation in the state. The yield is low due to local seed and traditional agronomical practices. Hybrids and composites are the high yielding varieties of maize, which have the potential of out yielding the local variety by many fold. We can boost maize production by adopting suitable cultivation practices.

Crop cultivation involves intensive tillage, which consumes a major portion of energy and cost. Nielsen (1990) reported that labour requirement could be reduced by 55-65 % in reduced tillage compared with conventional methods. Also, fuel

consumption has reduced from a maximum of 49 l/ha for ploughing to minimum of 18 l/ha for direct drilling. Tillage is one of the major operations of crop production and is an important contributor to the total cost of production. The rising cost of hydrocarbon fuels, their non-availability and the knowledge that they are non-renewable, along with the availability of herbicides coupled with the motive of reducing the cost of production, has provided enough incentive to researchers to investigate tillage operation more closely. Energy is used mainly for the agricultural operations of planting, fertilizer application, harvesting and transportation. It is directly related to production per worker and indicates the level of prosperity achieved by any country. Application of organic manure with inorganic fertilizer to integrated nutrient supply has shown encouraging results on crop production as well as soil health (Pathak et al., 2002). Continuous application of high amounts of only inorganic fertilizer has effects leading to decline in productivity due to limitation of one or more of the micronutrients (Nambiar and Abrol, 1989). Organic materials have the capacity to improve

hydro-physical environment, nutrient use efficiency and fertility status of soil and sustainable crop production, thereby increasing benefit cost ratio (Wani et al., 1994). Integrated supply of nutrients through organic and inorganic sources is a better option for sustainable crop production in the different agro-ecological regions of the country (Swarup, 1988). Keeping this in view, an experiment has been conducted to assess the impact of low-till systems and nutrient management on crop yield.

## Materials and Methods

Experiments were conducted at the project farm of Dryland Research Sub Station, SKUAST-Jammu, located at the Pathankot-Jammu National Highway. The project farm is situated at 32° 39' North latitude and 74° 53' East longitude at an elevation of 332 meters above the mean sea level. The project farm represented the true kandi belt of Jammu plain areas and part of Kathua and Udhampur districts of Jammu province.

The experimental soil was sandy loam in texture. The pH value ranged from 6.2-6.8, depth of the soil var-

ied from 70 cm to 110 cm. Organic carbon percentage range was 0.22 to 0.50 and available nitrogen range was 144 to 207 kg per hectare. The soils were low to very low in moisture retention. The experiment was initiated in the year 2000 and is continuing. In this paper, three years data, starting from 2003 to 2005, were used. Conventional tillage constituted one ploughing, two diskings and two tillings followed by planking. Reduced tillage constituted one disking + one cultivator followed by planking with interculture and weeding. The manurial value of compost (N = 0.5 %) were computed. Weeds were control by manual weeding as well as by using blade/rake as and when needed and by weedicide as per treatment. The crop was harvested at maturity and grain and stover yields were collected. Analysis of variance was used.

There were 27 plots (3 tillage × 3 fertilizer × 3 replications) in the experiment.

The tillage and fertilizer treatments included:

### A. Tillage

1. Conventional tillage + interculture
2. 50 % conventional tillage + in-

**Table 1** Grain yield of maize (q/ha) in different treatments during 2003 to 2005

Treatment	Average grain yield of maize, q/ha				SD	CV (%)
	2003	2004	2005	Mean		
<b>A. Tillage</b>						
T <sub>1</sub> = Conventional tillage + Interculture	17.96	25.58	17.96	20.50	4.40	21.46
T <sub>2</sub> = 50 % CT + Interculture	15.24	24.83	16.29	18.79	5.26	28.00
T <sub>3</sub> = 50 % CT + Weedicide + Interculture	16.20	26.58	17.71	20.16	5.61	27.81
Mean	16.45	25.66	17.32			
CD (5 %)	2.04	NS	NS			
SD	1.37	0.43	0.90			
CV (%)	8.38	1.71	5.20			
<b>B. Sub treatment</b>						
F <sub>1</sub> = 100 % Nitrogen through organic manure	14.66	23.41	15.37	17.81	4.86	27.28
F <sub>2</sub> = 50 % dose of Nitrogen through inorganic + 50 % N through organic manure	15.96	26.00	17.58	19.85	5.39	27.16
F <sub>3</sub> = 100 % Nitrogen through inorganic fertilizer	18.79	27.58	19.34	21.90	4.92	22.48
Mean	16.47	25.66	17.43			
CD (5 %)	0.842	2.76	1.64			
SD	2.11	2.11	1.98			
CV (%)	12.82	8.20	11.38			

terculture

3. Conventional tillage + interculture + weedicide

#### B. Fertilizer

1. 100 % N through organic fertilizer
2. 50 % N through organic fertilizer + 50 % N through inorganic fertilizer
3. 100 % N through inorganic fertilizer

## Results and Discussion

### Effect of Tillage and Fertilizer on Grain Yield of Maize

The average of three years data (Table 1) revealed that the highest maize yield of 20.50 q/ha (with 21.46 % variation) was recorded in T<sub>1</sub> (conventional tillage + interculture) followed by T<sub>3</sub> (50 % conventional tillage + weedicide + interculture) with a grain yield of 20.16 q/ha (with 27.81 % variation). Nitrogen application through different sources gave the highest average grain yield of 21.90 q/ha (22.48 % variation) with F<sub>3</sub> (100 % Nitrogen through inorganic fertilizer) followed by F<sub>2</sub> (50 % N through organic + 50 % N through inorganic fertilizers) with a grain yield of 19.85 q/ha (27.16 % variation) and the minimum grain yield of 17.81 q/ha (27.28 % variation) with F<sub>1</sub> (100 % N through organic manures). The sustainable yield index (SYI) of 0.71 was recorded by conventional tillage + interculture followed by 50 % conventional tillage + weedicide + interculture (0.70). Among different sources of nitrogen application, 100 % nitrogen through inorganic fertilizer recorded the highest SYI of 0.81 in the study. The tillage treatment had a variation of 1.71 to 8.38 %, while fertilizer treatments had a variation of 8.20 to 12.82 % in different seasons.

The main plot effects deviated from average in the first year of experimentation (Table 3). Fertilization effects (sub-plot effects) were consistent over all the three years;

however, Main effects of treatments T<sub>1</sub>, T<sub>2</sub> and T<sub>3</sub> showed non-significant differences at CD 5 % during years 2004 and 2005 (Tables 2 and 3). However, main effects of sub-plots, i.e. fertilizer levels, showed distinct effects on yield per plot. Maximum average yield per plot (5.20 kg) was realized under F<sub>3</sub> with 100 % fertilization with inorganic N and corresponding lowest yield per plot (4.27 kg) for F<sub>1</sub> with organic manuring. The mean squares due to fertilizer combination were significant over all the years (23.01, 20.74, 16.28); however, the interaction component tillage × fertilizer source over the years reflected non-significant variability, which indicated that no specific tillage method was effective for a particular source of fertilizer. This supported the importance of varying fertilizer sources in effect-

ing variations in grain yield per plot in maize. Coefficient of variability for both Error a (main plot error mean square) and Error b (sub-plot error mean square) was below 20 % which indicated that variance due to chance error was well under control during all the three years and, hence, results obtained were statistically robust. In conclusion, it can be suggested that it is the inorganic source of N that gave highest grain yield per plot irrespective of the method of tillage adopted. Also no significant effects of tillage method were found to be critical in improving yield per se of maize under rain-fed conditions.

### Effect of Tillage on Energy Requirement and Cost of Cultivation

The energy requirements for the production of maize in Punjab, M.P

**Table 2** Grain yield of different combination of tillage and fertilizer for the year, 2003-05

Year		F <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>	Mean
2003	T <sub>1</sub>	15.41	17.75	20.66	17.96
	T <sub>2</sub>	14.00	14.83	16.91	15.24
	T <sub>3</sub>	14.58	15.29	18.75	16.20
	Mean	14.66	15.96	18.79	16.46
2004	T <sub>1</sub>	23.16	25.54	28.03	25.58
	T <sub>2</sub>	23.54	25.00	25.95	24.83
	T <sub>3</sub>	23.58	27.50	28.75	26.58
	Mean	23.41	26.00	27.58	25.66
2005	T <sub>1</sub>	15.83	18.33	19.71	17.96
	T <sub>2</sub>	14.71	16.24	17.87	16.29
	T <sub>3</sub>	15.66	18.16	19.33	17.71
	Mean	15.37	17.58	19.34	17.29

**Table 3** Analysis of variance for main and sub-plot factors in maize

Source	DF	Mean sum of squares		
		2003	2004	2005
Replication	2			
Tillage	2	5.33	7.77*	6.40
Error a	4	9.64**	5.37	4.38
Fertilizer	2	23.01**	20.74**	16.28**
Tillage × Fertilizer	4	0.78	1.75	1.37
Error b	12	6.35	3.87	1.40
C.D. (T) at 5 %		0.254	NS	NS
C.D. (F) at 5 %		0.258	0.639	0.384
C.D. (Error a)		4.91 %	6.79 %	9.31 %
C.D. (Error b)		6.37 %	10.13 %	9.02 %

\*\* , \* indicated significant at 1 and 5 %, respectively

West Bengal, Tamil Nadu and U.P. was in the range of 2,322-13,110 MJ/ha (Singh et al., 1997). Out of three years of experimentation, reduced tillage had significant influence on the grain yield as well as conservation of input energy. The energy requirement for all three treatments, i.e. T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub>, was 5,013.8, 4,348.34 and 3,625.39 MJ, respectively, for maize (Table 4). Sharma et al. (1984) found that the no tillage system required the minimum energy (0.56 kWh/q of grain) and reduced cost of production (Rs.2.89/q of grain) about 1.5 times higher in conventional systems (0.69 kWh/q of grain and Rs.4.23/q of grain). Weeding interculture was the most energy intensive (63.83 percent of total human energy) and costliest of operation (Rs.2,082.30/ha) in growing maize. Marginal farmers recorded highest profit (Rs.6,631.71/ha) followed by small farmers (Rs.4,627.32/ha) and medium farmer (Rs.3,689.25) and the trend clearly supports the need for mechanizing farm operation

for maize production (Lidhoo, 2004). The benefit cost ratio ranged from 1.52: 1 to 0.36: 1 (Table 5).

### Effect of Resource Management on Grain Yield of Wheat

The average of three years data (Table 1) revealed that the highest grain yield of wheat of 29.33 q/ha (26.09 % variation) was recorded in T<sub>3</sub> (50 % conventional tillage + weedicide + interculture) followed by T<sub>1</sub> (conventional tillage + interculture) with a grain yield of 27.87 q/ha (27.06 % variation). Mishra et al. (1982) reported that yield was not affected significantly with varying tillage intensities ranging from minimum to traditional tillage system. It was also reported by Saxena et al. (1976) that wheat yield and attributes, viz. ear length, grains/ear, grain weight and 1000 grain weight, were significantly higher under minimum tillage than those obtained under conventional tillage.

With regard to nitrogen application through different sources, the

highest average grain yield of 29.00 q/ha (with 28.28 % variation) was recorded with F<sub>3</sub> (100 % nitrogen through inorganic fertilizer) followed by F<sub>2</sub> (50 % N through organic + 50 % N through inorganic fertilizers) with a grain yield of 28.25 q/ha (with 26.84 % variation) and the minimum grain yield of 25.76 q/ha (with 25.89 % variation) was recorded in F<sub>1</sub> (100 % N through organic manures). The tillage treatment had a variation of 3.78 to 9.09 %, while fertilizer treatments has a variation of 4.32 to 7.26 % in different seasons.

### Energy Requirement and Cost of Cultivation

The energy requirement for all three treatments, i.e. T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub> was 2,907.53, 2,281.56 and 2,227.20 MJ, respectively, for wheat (Table 3). Sharma et al. (1984) found that the no tillage system required the minimum energy (0.56 kWh/q of grain) and reduced cost of production (Rs.2.89/q of grain) about 1.5 times higher in conventional systems (0.69 kWh/q of grain and Rs.4.23/q of grain). Out of three years of experimentation, reduced tillage has significant influence on the grain yield as well as conservation of input energy. Srivastava (1982) observed that seedbed preparation and sowing together consumed nearly half of total operational energy for wheat production and also reported that a saving of 40 % energy in seed bed preparation was observed under minimum tillage in comparison to optimum tillage without affecting wheat yield significantly. The marginal farmers recorded highest profit (Rs.6,631.71/ha) followed by small farmers (Rs.4,627.32/ha) and medium farmers (Rs.3,689.25). The trend clearly supported the need for mechanizing farm operations for maize production (Lidhoo, 2004). The net income was higher in reduced tillage systems than conventional tillage and the benefit cost ratio was also higher

**Table 4** Operational energy involved in different treatments

Operations	Energy in MJ/ha		
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>
Tillage	2,545.00	1,766.54	1,632.19
Layout and sowing	549.50	560.00	545.40
Weedicide application	-	-	45.40
Hoeing/inter-culture	998.50	1,100.90	550.30
Earthing up	544.50	560.20	520.30
Harvesting	175.50	170.30	173.60
Threshing & cleaning	200.80	190.40	158.20
Total	5,013.80	4,348.34	3,625.39

**Table 5** Total monetary returns and net profits in different combination of tillage and fertilizer

Main treatment	Sub treatment	Grain yield, q/ha			Average, q/ha	Net return, Rs.	B:C
		2003	2004	2005			
T <sub>1</sub>	F <sub>1</sub>	15.41	23.16	15.83	19.21	4,352	0.36
	F <sub>2</sub>	17.75	25.54	18.34	20.52	6,282	0.56
	F <sub>3</sub>	20.66	28.03	19.71	22.79	10,403	1.21
T <sub>2</sub>	F <sub>1</sub>	14.00	23.54	14.71	17.40	4,165	0.39
	F <sub>2</sub>	14.83	25.00	16.24	18.77	6,116	0.63
	F <sub>3</sub>	16.91	25.95	17.87	20.24	9,815	1.45
T <sub>3</sub>	F <sub>1</sub>	14.58	23.58	15.66	17.93	4,152	0.37
	F <sub>2</sub>	15.29	27.50	18.16	20.29	6,643	0.64
	F <sub>3</sub>	18.75	28.75	17.58	22.24	10,593	1.52

in reduced tillage systems and ranged from 1.41: 1 to 1.08: 1

## Conclusion

The results showed that combination of tillage and interculture gave the highest maize grain yield and highest average grain yield by application of nitrogen as inorganic fertilizer. Also, weeding was the most energy intensive and expensive operation. The highest grain yield for wheat was with the 50 % conventional tillage + weedicide + interculture. Inorganic nitrogen gave the highest grain yield. In general, reduced tillage had significant influence on the grain yield as well as conservation of input energy.

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(Continued from page 77)

## Constraction and Performance Evaluation of a Local Device for Separating Sunflower Seeds and Environment Preservation

about 12 men  $\times$  10 = 120 L.E/fed.

Thus, cost of mechanical cost equaled 34 % of manual cost.

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# Status of Post Harvest Technology of Guar (*Cyamopsis Tetragonoloba*) in India



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## Abstract

The guar (*Cyamopsis tetragonoloba*) is one of the most important commercial crops grown in arid and semi-arid regions of India and contributes to 80 % of total world production of guar. The guar processing industries in India are mainly located in Rajasthan, Haryana and Gujarat states. Out of 150 guar split manufacturing industries, about 125 are located in Jodhpur (Rajasthan). The capacity of plants varies between 3,000-5,000 tonnes per year. The seed contains 30-35 % galactomannan located in the endosperm (also called guar gum split). Guar is processed using dry milling method in which the seed is split in to two halves using a burr mill. The germ is separated from cotyledons with a pin mill. The splits are heated for 10-15 min followed by dehulling using a dehuller. The hull and germ free cotyledons are known as guar gum splits. Grinding of these splits gives refined guar gum powder that has various food and industrial applications. The powder is soluble in cold as well as hot water and pro-

duces viscous gel. About 80 % of the guar gum produced in India is exported to various countries. The status of guar industries in India, its export potential, properties of guar gum powder, various uses and problems associated with this industry are discussed in this paper.

## Introduction

The cluster bean (*Cyamopsis tetragonoloba*) is called Guar in India. The word "Guar" is derived from Sanskrit word "Gau-ãhãr" which means cow fodder. It is a leguminous crop and up to 1953, was used as cattle feed (Bhan and Prasad, 1967). It has originated from the Indian sub-continent and can be successfully grown in arid regions. The plant is thin but strong and reaches one-meter height at its full growth (**Fig. 1**). The optimum sowing time of the guar is first fortnight of July (Kumar and Singh, 2002). It is harvested in the end of October. The harvesting is done manually in India. Green pods of the guar are used as a vegetable for human con-

sumption. It is also used as a green manure crop. However, the principal use and economic importance of guar lies in its industrial processing into guar gum powder.

Unlike the seeds of other legumes, the guar seed has a large endosperm. The concave shaped endosperm contains significant amount of galactomannan gum, which forms viscous gel in cold water. Refined guar gum powder has various food and industrial applications in ice

**Fig. 1** Guar plant



cream, as a stabilizer for cheese, instant puddings and whipped cream substitutes, as meat binder, in paper manufacturing, oil well drilling muds, explosives, and ore floatation.

### Area, Production and Yield

India is the world's largest producer of guar and is grown in the north-western parts of the country encompassing states of Rajasthan (Churu, Nagaur, Banner, Sikar, Jodhpur, Ganganagar, Sirohi, Dausa, Bikaner, Hanumangarh and Jhunjhunu districts), Gujrat (Kutch, Banaskantha, parts of Mehsana, Sabarkantha, Vadodara and Ahmedabad districts), Harayana (Bhiwani, Gurgaon, Mahendragrh, Hisar and Rewari districts) and Punjab (Bhatinda, Ferozpur, Muktsar and Mansa districts).

India accounts for 80 % of the total guar produced in the world and Pakistan at second place, shares 15 % of total world production. The guar crop was estimated to be grown on 2 Mha in India in 2003-04 (Anonymous, 2006). The state of Rajasthan alone comprises almost 78 % of the area under guar (Kumar and Singh, 2002). Estimated production of guar was 0.86 million tonnes in 2003-04 (Anonymous, 2006). Rajasthan ranked first in the production of guar with a share of approximately 70 % of total production in 2003-

04 and Haryana ranked second with a production of 0.59 lakh tones (Fig. 2). Productivity of guar in India was 322.7 kg/ha in year 2003-04.

### Nutritional Composition

The seeds of guar are light pale to brown in color. The seed is oval to round in shape. It is a dicotyledonous seed, rich in protein, lipids and minerals. Major constituents are: hull (14-17 %), endosperm (25-42 %) and germ (43-47 %). The endosperm is rich in galactomannan gum. The average composition of guar seed is given in Table 1 (Das and Arora, 1978).

The protein content of guar seeds range from 24.5 to 34.0 % at 10 % moisture content (w.b). Contrary to the other legumes, the germ portion of the guar seed is quite high (43-47 %) and constitutes mainly protein. The seed also contains 3.1-7.5 % oil (Joshi et al., 1990) that is mainly located in germ.

A considerable amount of carbohydrate (78-82 %), in the form of galactomannan, is present in the endosperm of guar seed (Das and Arora, 1978). It is the most important constituent of the guar and has many food as well as industrial applications. It is composed of D-galactopyranose and D-mannopyranose units. Joshi and Arora (1993) reported the analysis of the

endosperm, popularly known as guar gum (Table 2). The molecular weight of the galactomannan varies from 1.5 to  $2.0 \times 10^4$ .

The germ and hull of guar seed together constitute guar meal after processing. It is a rich source of protein and compares well with other vegetable protein source like oilseed cake. The amino acids composition of proteins compares well to that of other legume proteins (Ramakrishnan, 1957). The hull and germ contain a considerable amount of crude fiber and anti-nutritional factors, which make them, unfit for human consumption (Bakshi et al., 1964). Anti-nutritional factors namely trypsin inhibitors, lectin, and saponins have been reported in guar seed (Vidyasagar et al., 1978; Gupta, et al., 1978; Arora and Joshi, 1980) in addition to several toxic compounds (gallotannons, gallic acid and its derivatives, myricetin-7, glucocide-3, kaempferol-7 glucocide 3-glucocide, kaempferol-3-rutinoside, kaempferol-3 glucocide, chlorogenic acid, caffeic acid and ellagic acid) (Kaushal and Bhatia, 1982). Several treatments have been reported to detoxify the guar meal for animal feed uses. Kawatra, et al. (1969) proposed acid and hot water treatment to detoxify guar meal. Kaur, et al. (1981) found

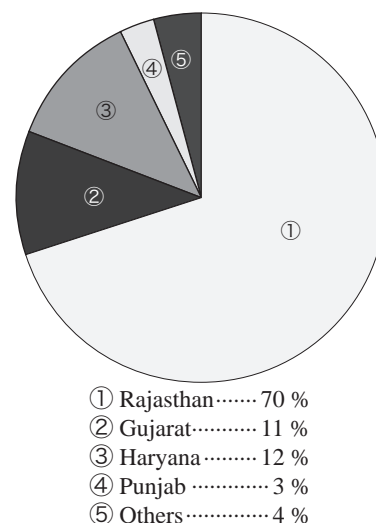
**Table 1** Average composition of different components of guar seed at 10 % moisture content

Seed part	Protein, % (N × 6.25)	Ether extract, %	Ash, %	Crude fibre, %	Type of carbohydrate
Hull (14-17 %)	5.0	0.3	4.0	35.0	D-Glucose
Endosperm (35-42 %)	5.0	0.6	0.6	1.5	Galactomannan
Germ (43-47 %)	55.3	5.2	4.6	18.0	D-Glucose

**Table 2** Typical composition of guar gum powder

Constituent	Content, %	Metals	Content, ppm
Galactomannan	78.0	As	0.20
Water	12.0	Pb	0.03
Acid insoluble residue	3.0	Cu	2.50
Protein	5.0	Zn	5.60
Ash	0.6	Cd	0.05
PH (1 % solution)	6.5		

**Fig. 2** State-wise production share of guar in India



that the protein concentrate prepared from guar meal is free from toxic constituents and beany flavour and hence they used protein concentrate to fortify the biscuits (Kumar and Singh, 2002).

### Processing of Guar Seeds

It is aimed to get endosperm free of germ and hull (popularly known as refined guar gum splits, **Fig. 3**). The refined guar gum splits are further ground to powder and modified as per its uses. The process involves splitting the seed, separation of germ, dehulling, separation of hull, and grinding of the endosperm to different sizes and refining of the gum powder. Splitting and dehulling of the seed is done by two processes, i.e. dry grinding and wet milling (Gunjal and Kadam, 1991).

### Wet Milling Process

For wet milling, Patel (1958) ob-

tained a patent for guar gum separation in which guar hull is loosened using a chemical agent and also by cooking the seeds in water. Process flow diagram (Gunjal and Kadam, 1991) of this process is shown in **Fig. 4**, although no details of the specific unit operations have been reported.

### Dry Milling Process

For dry processing, Jiwaji Industrial Research Laboratory, Gwalior obtained an Indian patent "The process to obtain refined guar gum in pin-mill without using chemicals" in 1960. As reported in this process, the guar seed are split into two halves using a mill having two grinding surfaces rotating at different speeds. The mixture of endosperm and hull is heated to soften the hull and then fed into hammer mill where the hull is removed by abrasion. Then endosperm is pulverized to remove residual hull and germ. Gunjal and

Kadam (1991) also mentioned a dry milling process for processing guar seed as shown in **Fig. 5**.

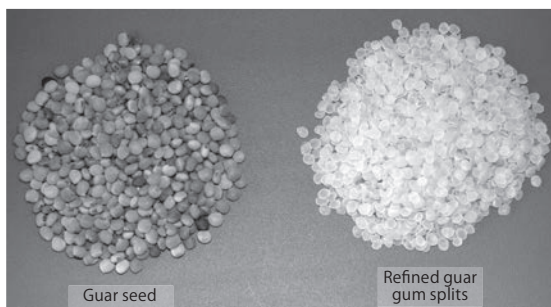
Recovery in wet processing methods is 8 to 10 % higher than that in dry processing method, but the quality of the guar gum produced is not good (Gunjal and Kadam, 1991). However, information on type of machines used, processing conditions and efficiency, are not reported in the literature. At present, none of the industries use these methods for processing of guar seed.

### Conventional Methods of Industrial Processing

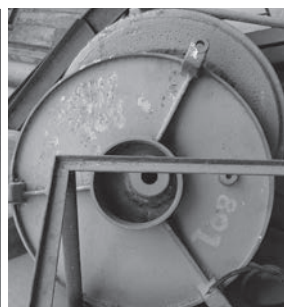
In order to obtain detailed accurate information regarding the prevailing method followed by guar industries for processing the guar seed, surveys were conducted in Jodhpur district (Rajasthan) and Bhiwani district (Haryana). The Jodhpur district of Rajasthan state is the main center for processing of guar. About 125 guar splits manufacturing units out of total around 150 units in India are located in the industrial area of Jodhpur. In Bhiwani, only 4-10 industries are installed. All industries are using the same type of machine and process for dehulling and splitting of guar seed. The capacity of these plants varies between 3,000 to 5,000 tonnes per year. Bigger industries usually set up two or three plants each of 5,000 tonnes per year capacity. Usually, plants run 24 hours from November to April (crop season) and 8-12 hours in remaining period, but bigger industries run their plants 24 hours throughout the year.

In industry, the guar seed is first cleaned and then graded into two to three sizes using a cylindrical grader and then fed at the center of horizontal burr (stone) mill. The upper plate of the burr mill rotates at 500-600 rpm whereas the lower plate is fixed. The clearance between stones is based on size of grain to be fed. Diameter of the plate is usually 61 cm and the coarse emery (14-18

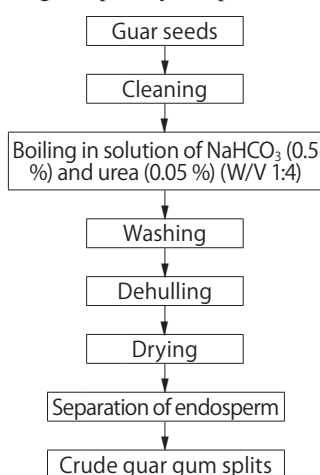
**Fig. 3** Guar seeds and refined guar gum splits



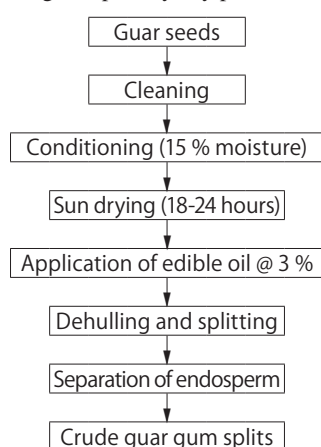
**Fig. 6** View of stones of burr mill



**Fig. 4** Flow diagram for milling of guar gum splits by wet process



**Fig. 5** Flow diagram for milling of guar gum splits by dry process





grade) stone is used (**Fig. 6**). Two to six burr mills are used in series depending upon the capacity of plant and dimensions of grain. The guar seed is split in to two halves in this machine. Some portion of germ is also separated during splitting. The seed is not treated prior to splitting. After splitting the grains, unsplit seeds and germ are separated using a cylindrical grader.

The splits are then passed through a germ separator (pin mill), where germ is removed from splits (**Fig. 5**). It consists of two mild steel plates of 53 cm diameter. One plate is fixed whereas the other plate rotates at 3,000 rpm. Three rows of pins of high carbon steel of rectangular rod shape (length 7.5 cm, width 2.5 cm and thickness 2.0 cm) are mounted on a moving plate (**Fig. 7**). Total of 26 pins are placed on the plate. Two rows of pins are mounted on the fixed plate. The material is fed through the center of the machine. The germ is removed from splits through shear, which comes out from the bottom of screen and carried away using a blower. It also removes the hull from the edges of splits and makes the later suitable for handling. A pin mill is used because the splits contain gum and it is a self-wiping type of machine and hence will not clog during operation.

Thereafter, the splits are heated in a kiln. It consists of a hollow mild

steel cylinder placed horizontally. Diameter of cylinder towards the entry side of splits is 61 cm and towards discharge side is 66 cm, thus a slope of 1° from horizontal is formed and hence material is conveyed towards discharge. Length of cylinder is 300 cm, which rotates at 30 rpm. The splits are fed inside of the cylinder. Outer surface of the cylinder is heated using oil fired furnace or firewood. The material remains inside the cylinder around 10-15 minutes and heating takes place through conduction. Temperature of the cylinder is not controlled, however in some industries, the temperature of splits coming out from cylinder is measured and varies from 120-140 °C. Heating is said to be completed when change in surface colour of splits starts. Heating is done to loosen the bond between hull and cotyledon so that dehulling of splits becomes easy.

After heating, the hot splits are fed to a dehulling machine at the top corner. It consists of a mild steel cylinder of 37 cm diameter on which blades of high carbon steel are fixed along the length of cylinder (**Fig. 8**). The capacity of the machine varies between 300-500 kg/h. Usually 3 teeth per inch blades are used. The height of teeth is 0.6 cm. The blades are fixed at a distance of 5 cm all along the periphery of the cylinder. A wire mesh screen (made from wire of 3-4 mm thick galvanized

iron) covers the cylinder. Clearance between tip of the blade and screen is about 0.4 cm. The cylinder with blades rotates at 1,400-1,800 rpm. Since the bond between hull and cotyledon is loosened during heating, subsequent cutting action, impact and friction between splits and blade as well as friction between splits results in dehulling. About 75 % of the cotyledon is dehulled in a single pass. Hence, usually two dehulling machines in series are used and even three machines are used in some industries.

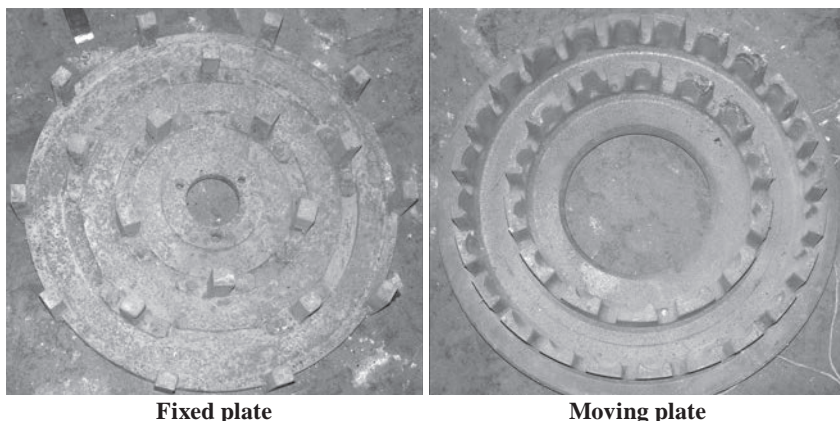
After dehulling, the splits are rapidly cooled. The cooled splits are fed to an air screen cleaner where brokens, and hull are separated and cleaned guar gum splits are conveyed for packaging. Based on the in situ information collected in this survey of guar gum industries, a process flow diagram for industrial processing of guar has been carefully prepared by the authors as shown in **Fig. 9**.

#### Layout of Guar Processing Plant

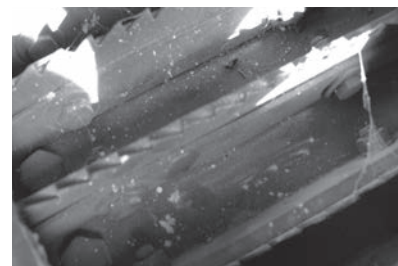
The guar processing machinery and plants are usually made locally. The plants of 1.0, 1.5 and 2.0 tonnes/hour capacity on raw material basis are manufactured. Usually 2, 4 and 6 burr mills are used for 1.0, 1.5 and 2.0 tonnes/h capacity plant, respectively.

A typical layout of a guar processing plant of 1.5 tonnes/hour is shown in **Fig. 10**. This plant has three sections; (i) seed splitting and germ separation section, (ii) split heating section and (iii) dehulling section.

**Fig. 7** Germ separator (Pin mill)



**Fig. 8** Inner view of dehulling machine



**(i) Seed splitting section:** This section consists of a seed cleaner (reel type), burr mills (seed splitter), conveyors for conveying after splitting, split separator (reel type), germ separator (pin mill) and a storage tank for storing germ free unhulled splits. All the machines including elevators run through a common shaft drive mechanism using a flat belt for power transmission. A 50 hp three-phase electric motor operates the common shaft.

**(ii) Split heating section:** This section consists of a heating cylinder, kiln and a conveyor. The splits are fed to the heating cylinder from a storage tank. The cylinder is fitted inside the kiln. Usually wood is fired to heat the outer surface of the cylinder. In some plants, diesel or kerosene oil fired furnaces are also used. The cylinder rotates slowly

(30 rpm) to facilitate uniform heating. A motor of 10 hp is used to transmit power to rotate the cylinder and run the conveyor. The pipes of the conveyor are insulated to avoid heat loss.

**(iii) Dehulling section:** This section consists of two dehullers, and a split grader along with cyclone dust collector. The heated splits are fed to first dehuller. Each dehuller is separately operated by electric motors of 75 hp. After dehulling, the powder is separated using a blower and connected with a common cyclone dust collector. The material is then fed to the split grader. It is operated by electric motor of 10 hp. After cleaning and grading, the guar gum splits are conveyed for packaging.

During dehulling process, around 18-25 % endosperms are converted

into powder or brokens and get mixed with hull. The broken endosperm and powdered hull is used as cattle feed. Thus a considerable loss during dehulling takes place. The following products are obtained through processing of guar seed.

**1. Guar gum splits (Guar gum):** Endosperms obtained after dehulling and separation operation. It is of high commercial importance.

**2. Guar by-product (Korma):** This is mixture of hull powder, and germ obtained during splitting and separation of germ. It is rich in protein and used as cattle feed.

**3. Guar meal:** Hull powder and powdered endosperm obtained during dehulling of the splits is called guar meal. It is used as cattle feed.

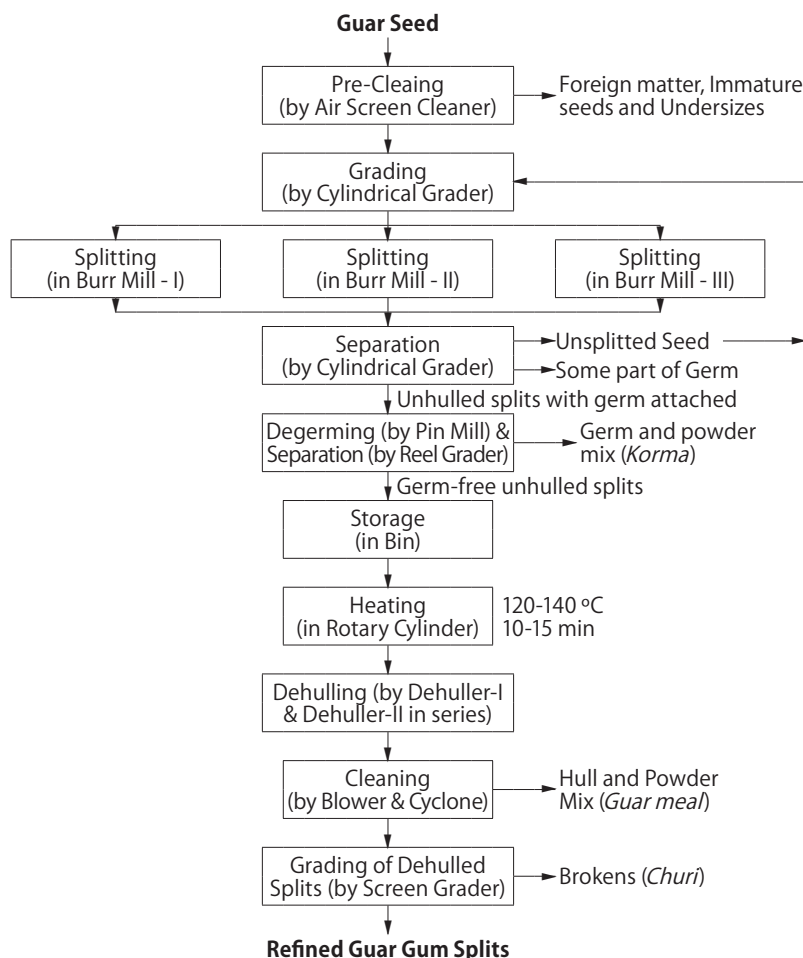
**4. Broken endosperm (Churi):** This is broken endosperms separated during grading of guar gum splits. It is considered low-grade splits.

The guar gum splits are usually of crescent or slightly concave shape. The splits are eventually ground to fine powder of different particle sizes depending upon their uses. Attrition mills, hammer mills or ultra fine grinders are used in the industry for this purpose. The moisture content of guar gum splits is usually adjusted to 10 % (wet basis) after grinding. Sometimes wet grinding of the splits is also done to get specialized products.

### Refining of Guar Gum

Refining of the guar gum powder is done to remove traces of germ, hull, and compounds other than galactomannan. It is generally done by repeated precipitation with alcohol. Isopropyl alcohol is mostly used in industries. Das and Arora (1978) stated that gum could be purified by mixing 1 kg of crude gum with 10 kg of 1:2  $\alpha$ -picoline- $\text{CCl}_4$  mixtures and drying the filtrate at more than 50 °C under reduced pressure to give 30 g of purified gum. However, the mass balance of purification appears to be erroneous. Relan et

**Fig. 9** Flow diagram for industrial processing of guar seed



al. (1991) purified the guar gum by repeated washing with 80 % alcohol at low temperature. The process flow diagram given by Gunjal and Kadam (1991) for refining guar gum powder is given in **Fig. 11**.

In some industrial processes, the guar gum powder is not washed using isopropanol. The guar gum splits are first screened and then flaked to reduce the thickness. These crushed splits are dried and then fed to the ultra fine grinder at uniform rate. Then the powder is separated using screens. Turbo screens are used some times as additional control. This gives guar gum powder of highest quality.

### Properties of Guar Gum Powder

Guar gum powder and its solution are practically odorless and have a bland taste. Its color varies from off white to very light yellow tan. Guar gum is a polysaccharide known as galactomannan, which consists of a mannose backbone with a galactose side chain. It contains 34.6 % D-galactopyranose units and 63.4 % D-mannopyranose units. These are high molecular weight hydrocolloid-ed polysaccharide units combined through glycosidic linkages. It is a straight chain compound of D-mannopyranose units joined by  $\beta$  (1-4) linkages with a side branching unit of every other mannose unit

by (1-6) linkage. It has a polymeric structure containing numerous hydroxyl groups, which are treated for manufacturing various derivatives used for special applications in various industries. The active sites present in the D-galactopyranose and D-mannopyranose bind the water molecules and hence galactomannan acts as very good water binder. Its molecular weight is  $220,000 \pm 10\%$ . The greater side branching accounts for its cold water hydration as well as its greater hydrogen bonding activity.

Solution of 1 % guar gum powder has a pH between 5.4 and 7.7. The optimum hydration of the powder takes place between pH 7.5 and 9. It has a buffering action and is stable in the solutions of pH 4 to 10.5.

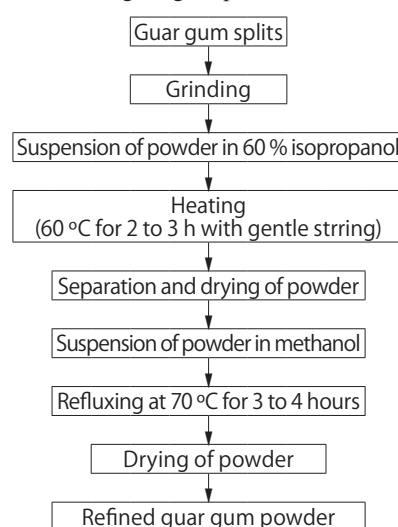
The most important characteristic of guar gum powder is its ability to disperse in water to form viscous colloidal dispersions or sols. The viscosity attained by the solution is dependent on time, temperature, concentration, pH, degree and type of agitation and particle size of the powder (Greenberg, 2000). A 1 % aqueous dispersion of a good quality guar gum has a viscosity of 3-6 Pa-s. In practical applications, a hydration time of about 2 h is required to reach maximum viscosity (Gunjal and Pawar, 1987). For some applications, in which there is a need of

an immediate high initial viscosity, very fine mesh guar gum powder can be used.

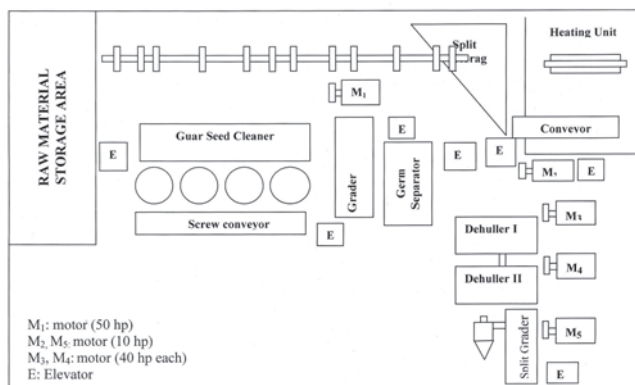
Viscosity of the guar gum powder varies with the particle size. Fine powders produce solution of high viscosity. The variation of viscosity with particle size is given in **Table 3**. It also varies with moisture content of the guar gum at the time of grinding.

Hydration rates, water binding properties and viscosity of the solution are affected by processing techniques used in making the gum powder and particle size. Dry processed guar has better hydration rate and water binding property.

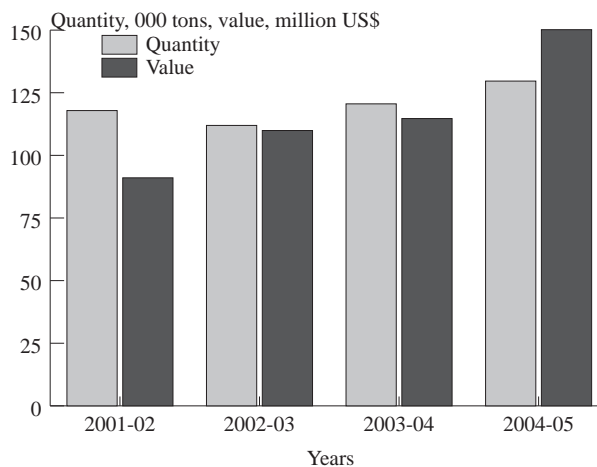
**Fig. 11** Refining process of guar gum powder



**Fig. 10** Guar processing plant layout



**Fig. 12** Export of guar gum from India



## Applications of Guar Gum

Approximately 1,500 patents on uses of guar gum in different applications have been registered throughout the world (Yadav and Ray, 2002). Guar gum is used in textiles, paper manufacture, oil well drilling mud, explosives, ore floatation, coal mining, tobacco, electrical and telephone, jute, varnish and coatings, ceramics, fire fighting, building construction material, water purifier, photography, dairy, pharmaceuticals, agriculture, cosmetics, soap industry etc. These uses depend upon the properties provided by very large molecule in various states of hydration, mostly in solution. Guar gum powder hydrates very easily to produce aqueous solutions because they prevent oil droplets from coalescing. They may also have the property of interfacial binding and thereby act as true emulsifiers.

Highly refined guar gum is used as a stiffener in soft ice creams, cheeses, instant puddings and whipped cream, and as a meat binder. Guar gum has important uses in frozen foods because it provides hydration and water binding properties. In preparation of cakes, adding guar gum allows single-step mixing, reduces mixing time, less crumbling tendency in finished cake, easy application of frostings, and greater moisture retention with prolonged shelf life. In canned meat products and pet foods, guar gum allows reduction of bumping tendency during the cooking of the meat and reduction of splashing and spilling of the product while filling. In dressings and sauces, it is used as thickener because of its ability to

**Table 3** Relationship of viscosity with particle size of guar gum powder

Particle size, Mesh	Viscosity, cps
80	Less than 3,000
100	3,000-4,000
200	4,000-6,000
300	3,000-6,000

disperse in cold water, compatibility with highly acidic emulsions and ability to add viscosity. It is used in noodles, jams, jellies etc. It can be used in many food applications and development of new products. It may increase the shelf life of onion and garlic paste by binding the free water and hence reducing the water activity.

Guar gum is more than 6 times as effective as starch in thickening power and is used for upgrading starches. Commercially important derivatives of Guar gum are:

- a. Hydroxy alkylated guar gum
- b. Carboxy methylated guar gum
- c. Oxidised guar gum
- d. Acetates of guar gum
- e. Cationic derivatives of guar gum
- f. Sulphated guar gum
- g. Guar gum formate
- h. Guar gum acrylamide
- i. Borate cross linked Guar gum
- j. Reticulated guar gum
- k. Carboxy methyl hydroxypropyl guar gum
- l. Depolymerised guar gum

## Status of Indian Industry

Indian guar gum industries are manufacturing either guar gum split or guar gum powder. Some industries, e.g. Lucid Gums and Chemicals Ltd., Vikas WSP Ltd., etc., also prepare specialized gums for specific industrial uses. There are more than 150 guar gum split manufacturing units in India and total installed capacity is more than 0.6 million tonnes per annum (www.

dsir.nic.in). All the split producing units have indigenous plant and machinery. Splits are available in various grades; in terms of purity as 90 %, 92 %, 95 % and 97 %. There are more than 25 units, which manufacture textile grade powder from splits. The total guar gum industry is estimated at about 0.225 to 0.250 million tonnes per annum capacity. The products manufactured in India are mainly food grade guar gum powder and some modified guar gum derivatives for textile printing industry.

There are a few large manufacturers like IGI, HICHEM, Dabur, Vikas WSP, Lucid, Hindustan Gums and Chemicals who produce value added derivatives for export as well as domestic market. The total domestic consumption of guar gum powder inclusive of splits from various end-use sectors is given in **Table 4** (www.dsir.nic.in). This reached over 50,000 tonnes by the year 2005. With India's captive consumption of guar gum about 50,000 TPA, the total demand of guar gum by the year 2006 has been estimated at 0.2 million tonnes.

## International Markets

India is major producer of guar in the world and guar gum splits and powders are being exported from India to more than 60 countries. Total export of guar gum was 0.13 MT worth 150 million US\$ in 2004-05 (**Fig. 12**). The growth in exports during the last 4 years was due to failure of guar crop in Pakistan. The major share of the guar processed in India is exported either in form of semi processed product, i.e. refined splits or in form of guar powder. In recent years, export of modified/derivatives gums has also started. USA is the major importing country followed by Germany. Both of these countries account for more than 50 % of India's exports of guar products. The other important importing countries from India are Netherlands, U.K., Japan and Italy.

**Table 4** Consumption of guar gum powder in Indian industries

Type of industry	Consumption including splits, tonnes
Textile	5,000
Paper	2,500
Explosives	1,500
Food and pharmaceuticals	800
Oil well drilling	130
Cosmetics	150

## Conclusions/Recommendations for Future Research

Guar gum is one of the most important agricultural products of India on account of its very high export potential. It is extracted from the endosperm of guar seed and constitutes mainly of galactomanan. The guar gum powder is a very good water binder and emulsifier. It is used in many food, industrial and pharmaceutical applications.

The traditional process prevalent in the industry for dehulling, through heating and scratching, is not capable of removing the hull neatly. Further, a substantial portion of the endosperm is lost in the form of brokens and the powder into the powdered hull, which is sold at a much lower price as cattle feed. Improved process and machinery, therefore, need to be developed to avert such quantitative and financial loss.

While the germ reportedly contains about 55 % of protein, it is not regarded suitable for human consumption. More intensive research and development efforts are essential to eliminate anti-nutritional factors and toxic compounds present in it in order to tap this rich source of protein.

There is a good potential for marketing of value added guar based health foods and medicines as dietary fiber, slimming-aid, fat replacers, etc. in the international markets.

For the long-term survival of guar industry, it is very important to develop domestic demand. The associations of guar gum processors may take up with the Ministry of Food Processing and authorities administering PFA to encourage use of guar in processed food and prescribe permissible limits. There should be considerable programmes planned by the research institutions to promote the applications of guar products as food ingredients. These programmes must address the Indian food processing industry and

the exporters within that sector.

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# Constraction and Performance Evaluation of a Local Device for Separating Sunflower Seeds and Environment Preservation

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## Abstract

The present study was conducted to develop a local device for separating sunflower seeds that would utilize both centrifugal and gravitational forces. The separation process was possible without crushing sunflower heads and, thus, decreased the power consumption with minimum environmental pollution and low separation cost. The study was conducted on the effect of different beater types (spike-tooth, angle-bar and knives), inner cone speeds (7.24, 9.11, 12.9, and 15.4 m/s) and seed moisture contents (26.9, 21.2, 15.7 and 9.8 %). Separating clearance was constant at 4/2 cm between the top and end of inner cone with outer cone. The calculated cost of separation showed that the best results were with the spike-tooth and 12.9 m/s inner cone speed at 21.2 to 15.7 % seed moisture content.

## Introduction

In Egypt, the gap between oil consumption and production is very high. Therefore, the direction is toward planting untraditional oil crops such as sunflower crop because it is an important oil crop in the world.

It ranks the second after soybeans with respect to oil production, can be cultivated in the new reclaimed areas, and is adaptable to a wide variation of soils and climatic conditions (Keshta et al., 1993). However, seed threshing and separation are still carried out manually. This method is not economical because it consumes more time with higher losses. Therefore, the main objective of this research is to develop a simple device for separating the seeds from sunflower heads without crushing the heads and with small losses for reaching higher efficiency of separating. Therefore, the present study is covered by the following objectives:

1. Construction of a device for separating sunflower seed that can be built locally and be suitable for small farms and decreased environmental pollution;
2. Evaluation of the device performance under different operating parameters and;
3. Evaluation of the cost of using the developed device.

El-Sayed (1992) designed and fabricated a conical sheller to be used for shelling peanuts. The performance of the sheller was investigated under different operating conditions. The minimum losses of shelling

were obtain at a revolving speed of 350 rpm. Hendawy (1995) designed and fabricated a conical prototype to be used for threshing different crops (berseem, wheat and bean). The design was a conical vertical drum rotating into another fixed outer drum. The results showed that the total efficiency was 95, 92 and 93 % for berseem, wheat and bean crops, respectively. Helmy et al. (2000) compared the performance of three types of threshing drums (triangular rasp-bar and triangular spike-teeth), four peripheral drum speeds (6.59, 8.06, 9.53 and 10.99 m/s), four concave clearance ratios (1.4, 1.8, 2.2 and 2.6) and three grain moisture contents (15.4, 20.9 and 28 %) that were tested to evaluate the performance of a modified Bamby 049 Bby thresher against the conventional Bamby 049 Bby and a local thresher (Misr CRS) in Turkey. The use of the spike-tooth drum and clearance ratio of 1.8-2.2 resulted in the lowest grain losses and grain damage. Likewise, a drum speed of 9.53 m/s and grain moisture content of 15.4-20.9 % produced optimum results for the modified thresher. The modified thresher obtained the highest threshing efficiency (98.08 %), with lowest total grain loss, grain damage and fuel consumption for various moisture

content and drum speed levels. The local thresher recorded the lowest threshing unit power requirement and threshing cost per unit production. El-Saharigi et al. (2002) compared a study between the traditional method and combine harvester in threshing sunflower crop. The optimum forward speed for harvesting sunflower was 3.5 km/h. This gave the least total losses and the maximum level of cleaning efficiency. Moisture content of 16 % (w.b.) gave the lowest level of total losses and seed damage and achieved the highest level of cleaning and threshing efficiencies, while the optimum cylinder speed and concave clearance were 500 rpm and 2.2 cm, respectively. The study also indicated that increased length of stalks decreased the total losses. Moussa and Mohamed (2005) reported that two mechanical harvesting methods (mower, then thresher) and combine harvester were compared with the traditional method (manual, then thresher). The mechanical harvesting methods were done at five different field speeds (2.5, 3.1, 3.6, 4.0 and 4.5 km/h) for mower and combine. Three different drum speeds (450, 500 and 550 rpm) were also effected

on grain losses and damage grain for combine and thresher machines at three different moisture contents 8.78, 10.68 and 13.37 %. Increasing thresher drum speed from 450 to 550 rpm increased threshing losses about 0.46 and damaged grain by 1.35 % at a feed rate of 1 Mg/h. Garg et al. (1999) developed an axial flow sunflower thresher at different cylinder speeds to find out the best speed. The threshing efficiency was more than 99 % and cleaning efficiency varied from 71.33-89.66 %. Total grain losses were less than 1 % in most cases except at higher speeds.

## Materials and Methods

A conical device was designed and fabricated in El-Serw Agric. Res. Station, Damietta governorate, for separating sunflower seeds in the 2006 season as shown schematically in **Figs. 1, 2** and **3**. The new device consisted of main parts as follows:

1. Separating unit (two cones inner and outer cones and guide of the heads),
2. Cleaning unit (two sieves and fan) and

3. Power source (0.75 kW motor).

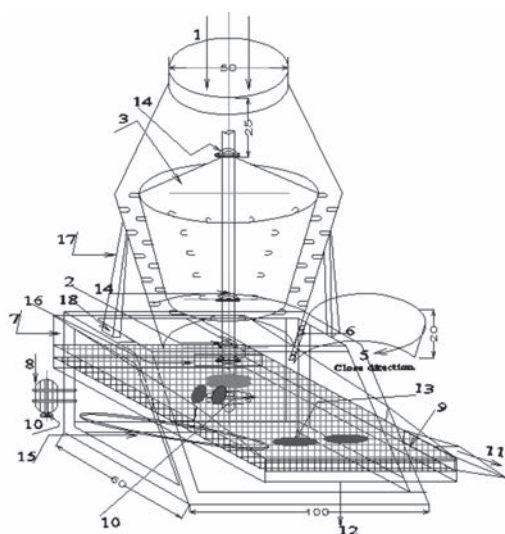
### Separating Unit

The inner cone had 50, 25 and 50 cm for upper and lower diameters and height, respectively. The knives, teeth or bars were arranged in ten rows and fixed on the outer surface in direction of the longitudinal axis. In the middle of the inner cone, an axis shaft was fixed and rotated at different speeds through transmission pulleys and belts powered by a 0.75 kW electric motor.

The outer cone was mounted on the frame around the inner cone and the guide of heads. The knives, teeth or bars were arranged in ten rows on the inner surface in the longitudinal direction. It had a feed opening (50 × 25 cm). The clearance between inner and outer cones cane was fixed (4/2 cm for upper and lower clearance).

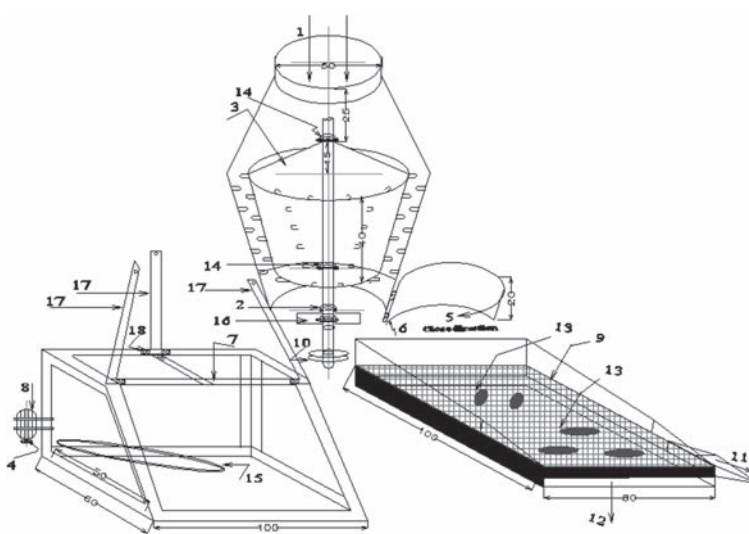
The guide heads were located above the inner cone on the same axis shaft from its middle for regulating the motion of sunflower heads towards the clearance between inner and outer cone. It has 30, 10 and 50 cm for height, upper and lower diameter to give upper clearance more than the radius of sunflower heads

**Fig. 1** Schematic diagram of the machine



1. Feed opening, 2. Bearing, 3. Heads guide, 4. Rotating shaft, 5. Door, 6. Hinges, 7. Standing fram, 8. Electric motor, 9. Sieves (upper and lower), 10. Pulleys, 11. Grains output, 12. Trashes output, 13. Sunflower heads, 14. Contact point, 15. V belt, 16. A fan, 17. Carrier, 18. Fixed point

**Fig. 2** Explode view of the machine



to allow them to fall gradually by gravity towards the separating zone. The clearance between the guide heads and outer cone narrow towards the separating chamber until the lower clearance of the guide is the same as the upper clearance of inner and outer cone.

The cleaning unit consisted of three main parts:

**A- A fan:** It was fixed on the axis end and rotated at the same rotating speed;

**B- The upper sieve:** It was made from wire mesh with 1.5 cm diameter holes and used to prevent any volume which is bigger than the seed size and;

**C- The lower sieve:** It was made from wire mesh with 0.5 cm diameter holes and used to prevent any volume which was smaller than the

seed size. The sieve attached with the outer cone at an angle of 300 to the horizontal. The separating material flowed on the sieve by gravity force and the sieve angle along with the vibration motion resulting in rotating the inner cone.

### Experimental Procedures

Vidok variety of sunflower was used in this study. The average of physical properties and characteristics of the Vidok variety are summarized as follows in **Table 1**.

The developed device was evaluated by the following main parameters:

1. Inner and outer cone with ten rows of spiked teeth (3 cm length and 1 cm dia. and 10 spike-teeth on every row), ten angle-bars (3 cm length and 0.2 cm thickness)

and ten rows of knives (3.0 cm length, 1.0 cm width and 0.2 cm thickness and 10 knives on every row) in direction of the longitudinal axis and fixed on every one. The positions were identified as B<sub>1</sub>, B<sub>2</sub> and B<sub>3</sub>.

2. Sieve dimension (50 × 75 cm).
3. Peripheral inner cone speed levels were (7.24, 9.11, 12.9 and 15.4 m/s) identified as S<sub>1</sub>, S<sub>2</sub>, S<sub>3</sub> and S<sub>4</sub>, respectively.
4. Separating clearance was constant (4/2cm at the top and end of inner cone according to many researches.
5. Seed moisture content levels were (26.9 21.2, 15.7 and 9.8 %) identified as M<sub>1</sub>, M<sub>2</sub>, M<sub>3</sub> and M<sub>4</sub>, respectively.

### Evaluation of the Device Performance

Efficiency was investigated according to El-Saharigi et al. (2002).

1. Seed damage (Sd %) was determined by taking 50 g samples and separating the seed damage (Wd %) relating to the total seed weight (Ws).

$$Sd = (Wd \times 100) / Ws, \% \dots\dots(1)$$

2. Separating efficiency (Sth) was evaluated by collecting the seed attached to the unthreshed parts of heads, separated by hand and weighed (Wunth) then related to total seed weighed.

$$Sth = (Ws - Wunth) / Ws \times 100, \% \dots\dots\dots(2)$$

3. Cleaning efficiency (Ec) was assessed by separating the foreign material (Wf) from 100 g sample as related to the sample weighed (Ws).

$$Ec = (Ws - Wf) / Ws \times 100, \% \dots\dots\dots(3)$$

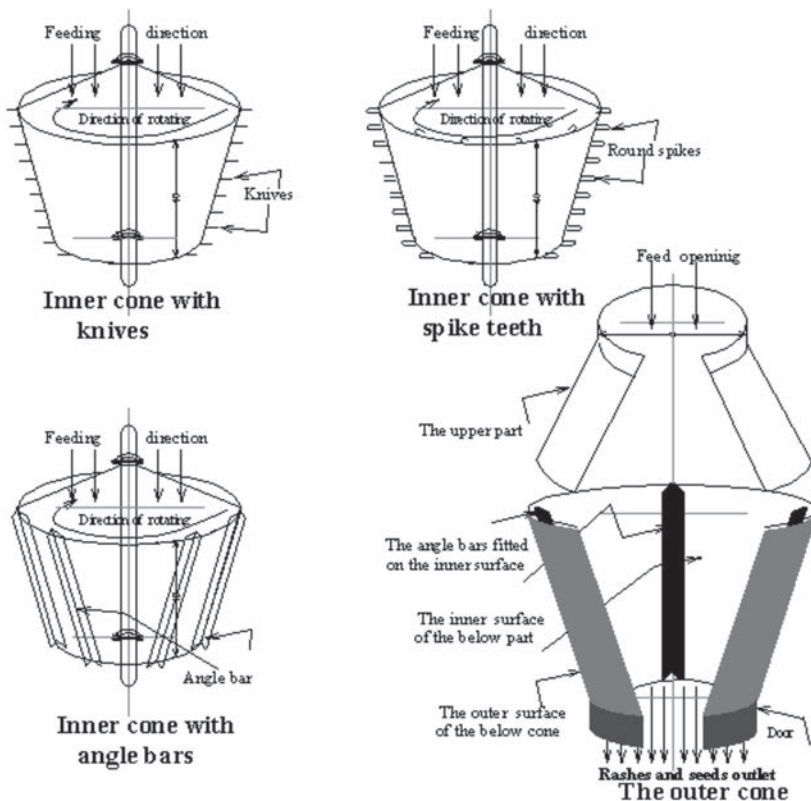
### Problems Identified During Developing the Separating Device

1. In primary tests, some discs (heads) move in a cycle motion on the top of the inner cone without inserting in the separating zone between inner and outer cones. This problem was

**Table 1** The average of physical properties and characteristics of the Vidok variety

Head dia, cm	Head thickness, cm	1000 seed mass, g	Seed yield, g/head	Seed length, cm	Seed width, m
18.9	3.2	59	162.1	0.9	0.5

**Fig. 3** Different types of the inner and outer cones





solved by fixing of the head guides above the inner cone. This gave good results by increasing separating capacity.

2. Inserting two discs (heads) together at the same time inside the clearance between the head guides and outer cone subsequently preventing falling of the discs (heads) into the separating zone. This problem was solved by fixing ten spike teeth (3 cm length and 1 cm dia.) on the perimeter top of head guides.
3. The first tests showed that a high amount of husks mixed with the seeds. It was necessary to fix a fan to push separating material and clean the seeds from foreign materials (husks and headpart). This problem was solved by fix-

ing a fan (4 blades) on the axis end below the inner cone and rotating it at the same rotating speed. The best results were with 8 cm blade length and 5 cm blade height.

4. It was noticed that the heads, after separating action, jammed at the end of the inner cone that resulted in more at the top than at the bottom diameter of the inner cone. This problem was solved by opening a door at the end of outer cone and led to increased seed separation.

inner cone that created centrifugal force on sunflower heads. Separated seeds moved downward by gravitational force without crushing the heads or causing environmental pollution. The threshing process was:

1. Accomplished without crushing sunflower heads and, subsequently, decreased the power consumption as well as threshing dust and environmental pollution;
2. Increased the rate of separating seeds and;
3. Decreased separating cost.

## Results and Discussion

Separating seeds was accomplished by action of the rotating

### Effect of Different Parameters; Beaters Type, Inner Cone Speeds and Seed Moisture Content on Device Performance

#### A. Separation Capacity: Figs.

Fig. 4 Effect of inner cone speed, knife type and seed moisture content on threshing capacity, kg/min

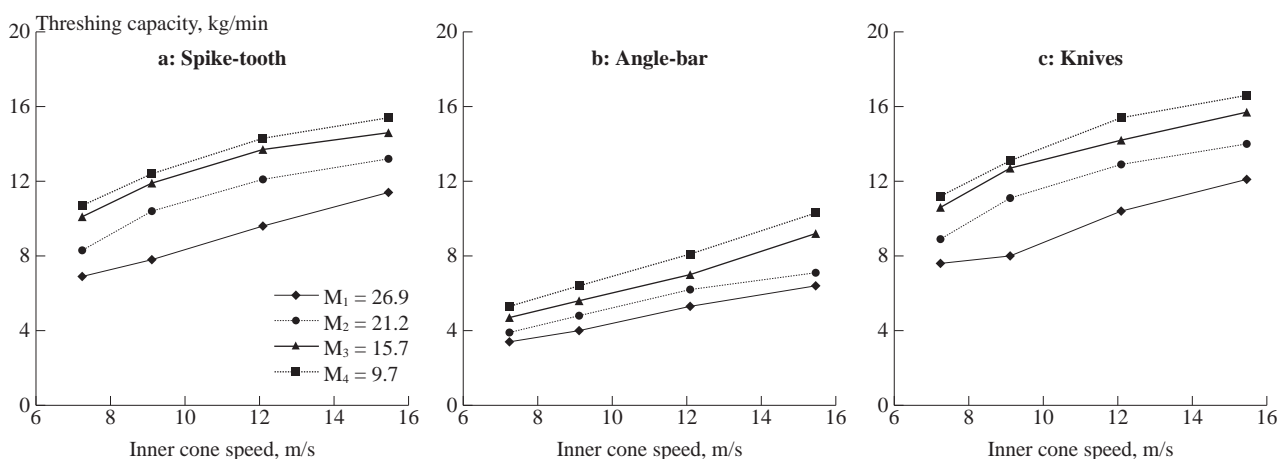
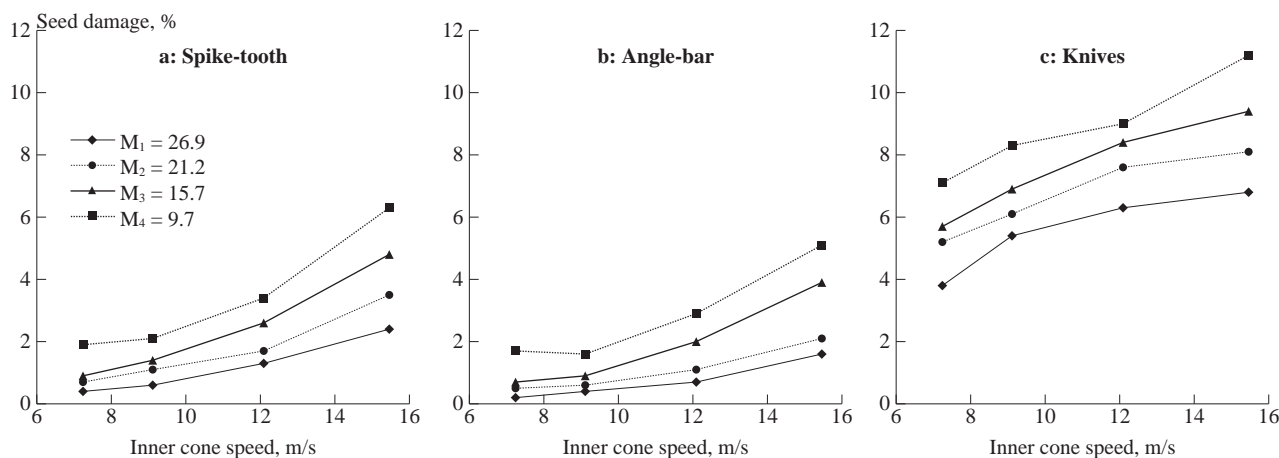


Fig. 5 Effect of inner cone speed, knife type and seed moisture content on seed damage percentage



4a, 4b and 4c illustrate the effect of beater types on separating capacity for different factors. The separating capacity with different beater types and separation speeds increased with decreased seed moisture content. This was because, at minimum moisture content, the seeds were somewhat inelastic with lower resistance to separation action. The maximum separating capacity was 16.6 kg/min for beater knives followed by 15.4 kg/min for spike-tooth and 10.3 kg/min for angle-bar.

The equations of Separating Capacity were:

$$\text{Capacity} = 9.9550 + 0.5580 \text{ speed} - 0.2529 \text{ seed M.C (R}^2 = 0.975 \text{ with spike-tooth);}$$

$$\text{Capacity} = 3.8880 + 0.478 \text{ speed} - 0.165 \text{ Seed M.C (R}^2 = 0.983 \text{ with Angle-bar ) and}$$

$$\text{Capacity} = 10.478 + 0.6042 \text{ Speed} - 0.2688 \text{ Seed M.C (R}^2 = 0.977 \text{ with knives).}$$

**B. Seed Quality:** The results were summarized in Figs. 5a, 5b and 5c. The seed damage increased and seed quality decreased with decreased seed moisture content and increased speed of inner cone with all types of beaters. This was because decreased seed moisture caused the seed to become hard shelled and increased separation speed led to increased impact forces imparted to seeds and subsequently increased the percent seed damage. Also, the percent-

age seed damage with angle-bar was smaller than spike-tooth and knives. On the other hand, the seed quality with angle-bar was higher than spike-tooth and knife beaters at different levels of seed moisture content. A higher percent of seed quality of 99.8 % was obtained with the smaller inner cone speed (7.24 m/s.) and higher seed moisture content (26.9 %) with angle-bar as beaters. The smaller percent of seed quality (88.8 %) was obtained using knives as beaters with higher inner cone speed (15.4 m/s) and minimum moisture content (9.8 %).

The equations for seed quality were:

$$\text{Quality} = 99.785 - 0.3997 \text{ Speed} + 0.1309 \text{ Seed M.C (R}^2 = 0.951 \text{ with spike-tooth);}$$

$$\text{Quality} = 99.521 - 0.3058 \text{ Speed} + 0.1211 \text{ Seed M.C (R}^2 = 0.931 \text{ with Angle-bar) and}$$

$$\text{Quality} = 93.783 - 0.4083 \text{ Speed} + 0.1894 \text{ Seed M.C (R}^2 = 0.981 \text{ with knives).}$$

**C. Separation Efficiency:** Figs. 6a, 6b and 6c show that, the un-separated seed decreased and separating efficiency increased with increased inner cone speed and decreased seed moisture content for all types of beaters. Beaters of knives gave higher efficiency than spike-tooth and angle-bar at different levels of seed moisture content and inner cone speed. The maximum

separating efficiency was (99.8 %) when using knives as beaters at higher speed of inner cone (15.4 m/s) and minimum level of seed moisture content of 9.8 %. Minimum separating efficiency of 93.2 % was obtained with angle-bar as beaters and the lowest inner cone speed (7.24 m/s) with maximum level of seed moisture content of (26.9 %).

The equations of Separation Efficiency were:

$$\text{Efficiency} = 98.322 + 0.144 \text{ Speed} - 0.064 \text{ Seed M.C (R}^2 = 0.956 \text{ with spike-tooth);}$$

$$\text{Efficiency} = 94.615 + 0.272 \text{ Speed} - 0.128 \text{ Seed M.C (R}^2 = 0.989 \text{ with Angle-bar) and}$$

$$\text{Efficiency} = 98.579 + 0.1220 \text{ Speed} - 0.0462 \text{ Seed M.C (R}^2 = 0.961 \text{ with knives).}$$

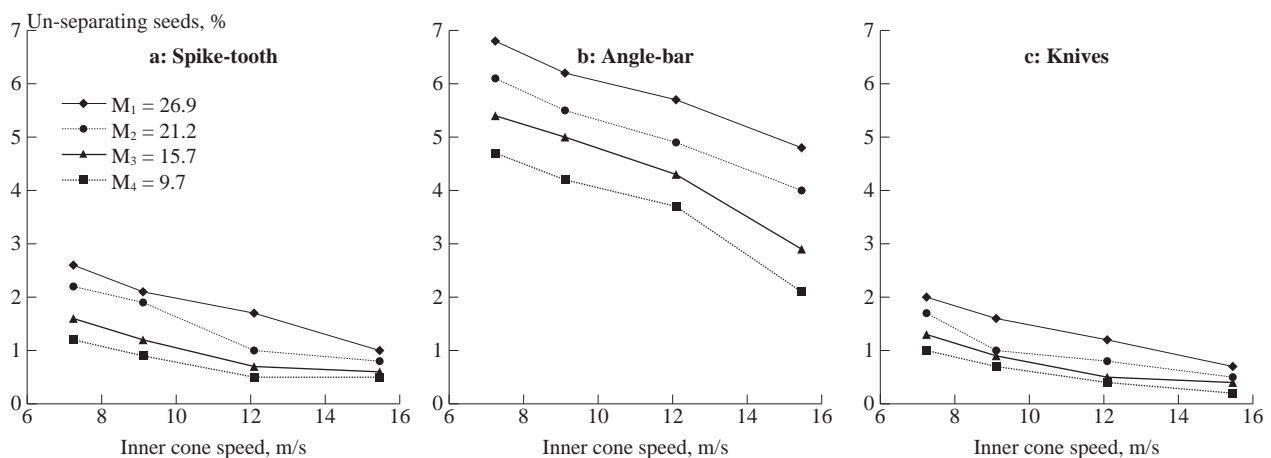
**D. Separation Cost:** The cost of separation was calculated according the declining-balance depreciation method (Metwalli, 1984) for the best results with the spike-tooth and 12.9 m/s inner cone speed at 21.2 to 15.7 % seed moisture content. It was found that, the device and labor cost = 8.6 L.E/h So, cost of separation for one ton = 10.46 L.E/h

One Feddan produced about 4 tons of sunflower heads.

Thus, cost of mechanical of separation of one Feddan = 41.84 L.E/fed.

**Manual Cost:** One Fadden needed  
(continued on page64)

Fig. 6 Effect of inner cone speed, knife type and seed moisture content on un-separating seed percentage



# Design of a Pollination Device for Palm Tree



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## Abstract

The aim of this study was to design, construct, and evaluate a simple pollination-device for date palm trees. The designed pollination device consisted of fan fixed on small 12-volt electrical motor, that was powered by a dry cell battery, pollination conical-hopper and a vibrated plastic roller (feeder) that was rotated by second small 12-volt motor and conical tubes

The conditions which gave adequate performance were those that carried material of “flour + fine bran” with a ratio of 1:1, air speed of 1.8 m/s, and quantity of mixture inside the hopper of 50 - 100 g (all sizes). This gave a maximum advance of 100 cm, a lateral spread of 40 cm and a mixture discharge of 0.3-0.33 g/s.

Date palms are considered one of the oldest trees known to ancient people as a source of food. However, recently the fruit growers have not been interested in increasing the date palm plantations due to problems of pollination, thinning and harvesting. All of these practices are still carried out manually, which consume a lot of time and cost besides the danger of palm climbing (Lovghavi et al., 1993).

The pollination operation of palm trees is considered one of the most important technical operations. The pollination operation needs trained workers who can climb the palm tree. In addition, because of the shortage of workers and increasing of manual cost, the pollination operation must be mechanized by machine operated from the bottom

of the palm tree. So, a pollination device put on the top of telescopic tubes of the machine was designed with the following advantages:

1. Simplicity and easy construction.
2. Uniform distribution of pollinate mixing,
3. Easy of control of discharge rate of pollinate mixing,
4. Light mass,
5. Ease of operation, adjustment, maintenance, and repairs, and
6. Low cost of the device.

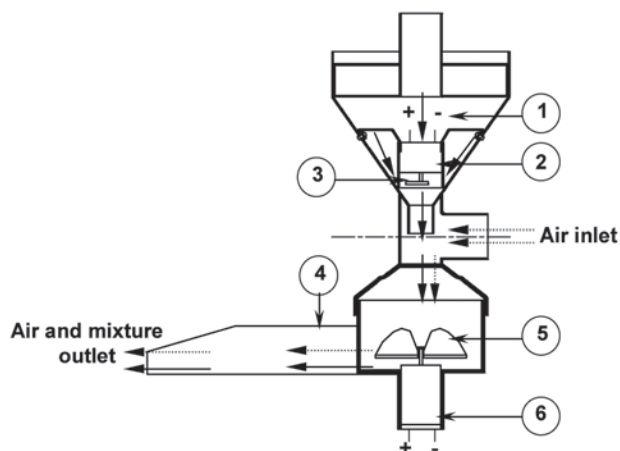
Awady et al. (1998) designed a pollination machine that consisted of a manual trailer, telescopic tubes and four pollination devices. Four pollination devices were developed and tested. Pollination devices were:

1. Blower fan with a conical tube that connects to a hopper of pol-

**Fig. 1** Photograph of a pollination device



**Fig. 2** Section of pollination device of palm tree



1. Pollination-grain hopper, 2. Vibrated plastic-roller, 3. Non-axial mass, 4. Conical tubes, 5. Fan, 6. 12 V electrical motor

## Introduction

Egypt is considered one of the greatest countries in palm date production in the world. The palm productivity in Egypt in 2002 was about 1.2 million tons from 10.4 million-palm which give fruit (total palm-trees of 14 million and area of 73.6 thousand feddan) (Badawy et al., 2003).

**Acknowledgment:** Heart-felt deep gratitude is expressed to my great friend Eng. Ahmed El Attar for his help to fulfil this work.

len mixture,

2. Steel wire rotating into a center of the conical tube,
3. A steel brush rotating into a conical hopper, whose bottom has a sliding gate, and
4. Conical tube with an air tube and manual blower.

The best system consisted of a pollination device with a fan blower. It gave a maximum reach of 75 cm and lateral spread of 60 cm. Yehia (2003) studied the design and operation factors of this machine and concluded that:

1. The average machine productivity was 33 palm trees/h,
2. The field efficiency was 76.8 %, and
3. Pollination cost with the designed machine was 0.12 LE/palm tree, whereas, the pollination cost by a traditional method was 2.5 LE/palm tree.

The present research is to study the design factors of a pollination device for date palm-trees.

## Review of Literature

Mousa and Eliwa (2000) found that the mechanical pollination of Hiany palm-tree gave a high fruit set and total yield compared to manual method. Awady et al. (2003a) designed, constructed, and evaluated a self-propelled machine for pollination of date palm-trees along with other services such as pest control and pruning. The designed machine consisted of a 4-arm stand,

telescopic tubes, and pollination or other devices. The main results were:

1. The average machine productivity was 21 palm trees/h,
2. Pollination cost for the designed machine was 0.15 LE/palm tree, whereas, the pollination cost by a traditional method was 2.5 LE/palm tree, and
3. The optimum design of 4-arms stand consisted of straight arms with about 2 m width and 20.5 cm height that gave the best stability.

Awady et al. (2003b) designed, constructed, and evaluated a self-propelled machine for pollination of date palm trees. The designed machine consisted of a self-propelled chassis, telescopic tubes, and pollination or other devices. The main results were:

1. The average machine productivity was 10 palm tree/h, and
2. Pollination cost for the designed machine was 0.74 LE/palm tree, whereas, the pollination cost by a traditional method was 2.5 LE/palm tree.

## Materials and Methods

The designed pollination device: It consisted of a fan fixed on a small 12-volt electrical motor, powered by a dry cell battery, pollination conical-hopper, a vibrated plastic roller (feeder) that was rotated by a second small 12-volt motor and conical tube. The pollination grains

drop from the bottom of the hopper on the fan and the fan air exits them to the palm tree (Fig. 1).

## Results and Discussion

### Density of Carrying Materials.

The density of flour, starch, bran, “flour + bran” with ratio of 1 : 1 and “flour + bran” with a ratio of 2 : 1 were 0.54, 0.47, 0.39, 0.41 and 0.42 g/cm<sup>3</sup>.

### Effect of Design Factors of Pollination Device on Discharge of Pollination Mixture:

#### a. The Gap Between Vibrated Roller and Hopper Sides

The best gap between vibrated roller and hopper sides was 0.5 mm. This gap gave a suitable mixture quantity (0.6-1 g/s flour) that could be carried by fan air. Clogging was caused with 0.75 and 1 mm gap.

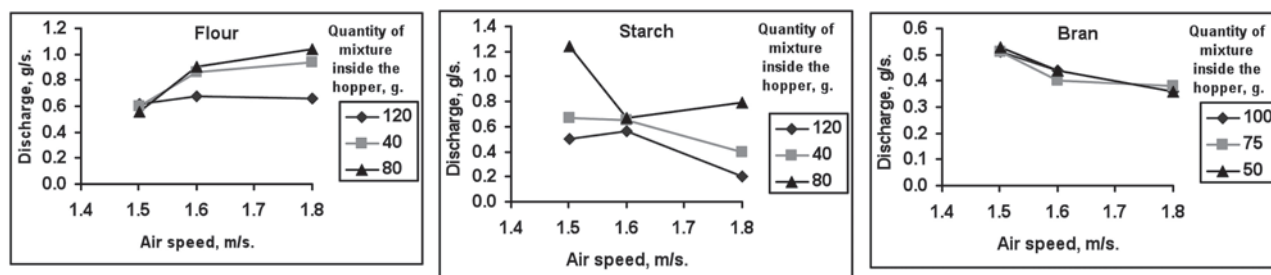
#### b. Air Speed

Figs. 3 and 4 show that the discharge ranges were 0.6-1, 0.2-1.24, 0.63-0.53, 0.27-0.33, and 0.26-0.34 g/s for flour, starch, bran, “lour + bran” with ratio 1:1 and “flour + bran” with ratio 2:1 respectively when air speed ranged between 1.5-1.8 m/s. The best air speed that gave a suitable and uniform discharge was 1.8 m/s.

#### c. Kind of Carrying Material

Figs. 3 and 4 show that the best carrying material that gave a uniform flow was “flour + bran” with ratio of 1:1. The mixture discharge ranged between 0.27-0.33 g/s at

Fig. 3 The relationship between air speed and discharge of pollination mixture at different mixture quantity inside the hopper for flour, starch and bran



different air speeds and mixture-quantities inside the hopper.

**d. Quantity of Pollination Mixture Inside the Hopper**

Figs. 3 and 4 show that the best quantity of pollination mixture inside the hopper that gave a uniform flow was 50-100 g (1/4, 1/2, 3/4 and full hopper). The mixture discharge ranged between 0.27-0.33 g/s using "flour + bran" carrying material with a ratio of 1:1 and at different air speeds and mixture-quantities inside the hopper.

**Effect of Design Factors of Pollination Device on Advanced of Pollination Mixture:**

**a. Air Speed**

Fig. 5 shows that the advance spread increased from 60 to 110, from 70 to 80, from 70 to 90, from 90 to 100 and from 90 to 95 cm by increasing air speed from 1.5 to 1.8 m/s for flour, starch, bran, "flour + bran" with ratio 1:1 and "flour + bran" with ratio 2:1, respectively. There was no effect of air speed on lateral spread.

**b. Kind of Carrying Material**

Fig. 5 shows that the maximum advance (90-100 cm) and lateral (40

cm) spread was obtained by using "flour + bran" with ratio 1:1.

**c. Quantity of Pollination Mixture Inside the Hopper.**

There is no effect of quantity of pollination mixture inside the hopper.

**Conclusion**

The best conditions which gave the best performance were carried material of "flour + bran" with ratio of 1:1, air speed of 1.8 m/s, and quantity of mixture inside the hopper of 50-100 g (all sizes). It gave a maximum advance of 10 cm, lateral spread of 40 cm and mixture discharge of 0.3-0.33 g/s.

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Fig. 4 The relationship between air speed and discharge of pollination mixture at different mixture quantity inside the hopper for "flour + bran" with ratio 1:1 and 2:1

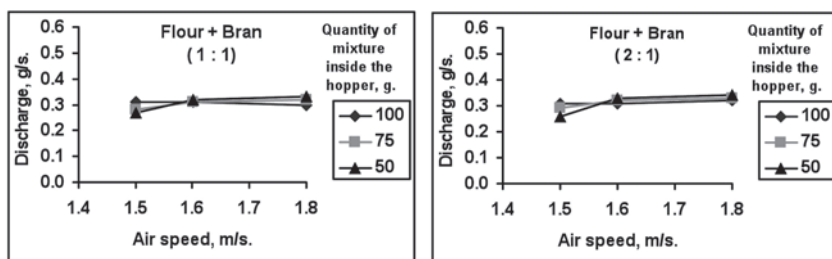
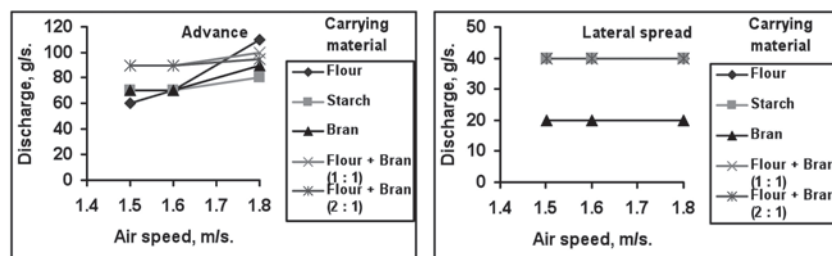


Fig. 5 The relationship between air speed and discharge of pollination mixture at different carrying-materials



# Small Scale on Farm Mechanization in Walnut Cultivation



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## Abstract

Walnut is one of the important horticultural crops of Kashmir valley with an area of more than 65,000 ha under walnut cultivation. The crop is of vital importance in improving economic status of people residing in remote areas of the Kashmir valley. During the reconnaissance survey carried out during (2003-04) in Baramullah and Kupwara districts of Jammu and Kashmir State of India. It was observed that most of the operation like harvesting, grading and nut cracking in the farmers fields are being carried out manually without the use of any kind of machines and implements. In the study development of manually operated walnut harvesters, pedal operated walnut grader and walnut crackers were carried out for improving the capacity, efficiency and reduced drudgery in walnut farming. The capacity and efficiency of all the fabricated implements were much higher than traditional methods employed for performing the operations. The average capacity of different fabricated walnut harvest-

ers Type I, Type II, Type III, Type IV was 25 kg/hr, 20 kg/hr, 24 kg/hr and 21kg/hr. The average grading capacity of pedal operated grader was 1.85 q/h, with an efficiency of 69 %. The average capacity of impact type walnut cracker was 3.5 kg/hr with an efficiency of 83 %. The breakages to the kernels were 5 %. The average breaking capacity of roller type walnut cracker was 20 kg/hr with an efficiency of 72 %. The breakages to the kernels were to the extent of 12 %. Time saving of 52.4 % and 656 % were observed as a result of use of impact type and roller type crackers, respectively.

## Introduction

The Persian walnut (*Juglans regia* L), known as the "English Walnut", belongs to family Juglandaceae. Major walnut producing centers are Germany, U.S.A., France, Iran and India (Anonymous, 1990). As far as the world production is concerned, Germany alone contributes about 30.6 % of total world production. In India, walnut grows in the North-

western Himalayan belt, which comprises of Jammu and Kashmir, Himachal Pradesh and Uttranchal between the elevations of 1,200 to 2,150 m above MSL. Walnut is one of the important fruits crops of the Kashmir valley. The state produces 85 % of the total production of the country and assumes a unique distinction and has a monopoly in the production of export quality walnut (Qureshi and Dalal, 1985). The walnuts produced in the state are renowned world over for their outstanding quality. The total area of Jammu and Kashmir state under walnut production is 64,130 ha, with production of about 86,263 Mt (Anonymous, 2001) with an average production of 1.4 t/ha. The average production in the state is very low as compared to other countries like Germany (3.37 t/ha), Iran (3.2 t/ha) and U.S.A. (2.64 t/ha) (Gadoo, 1997). The entire export grade of walnut from the country comes from J & K state with 5 % share in international market and ranks among five top producers of walnut in the world and earns about Rs. 120 crores foreign exchange for the

country (Anonymous, 2003).

Small scale mechanization is of vital importance for the walnut growing farmer because it is linked with the market price. Normally, all the operations like harvesting grading and cracking is done manually requiring a lot of physical work and time. Due to shortage of labour, farmers sell their produce without proper grading cracking, drying, and washing as a result of not getting appropriate dues for their produce.

Therefore, the objective of the study was to design and develop low cost machines and implements like harvesters, graders and crackers for performing various operations like harvesting, grading and cracking in walnut cultivation.

## Material and Methods

### Walnut Harvesters

The harvesting operations are mainly done during the month of

September and October depending upon varietal and climatic differences. The farmers mainly adopt manual labourers for performing harvesting operations in walnuts, pickle nuts etc. The height of an adult walnut tree is more the 40 ft. It was observed that a lot of fruit in the upper reaches of the tree remains unplucked due to inaccessible heights. It has also been reported that many injuries to the labourers and farmers occur during the harvesting season, as, they do not possess any suitable mechanical tool to

perform harvesting operations.

The fabricated harvesters work on the principle of hold and twist type device and are based on the hand picking mechanism where individual fruit is held between jaws of the harvester and then twisted to shear off the stock (**Fig. 1**). Taking this factor into account a number of manually operated harvesters (**Fig. 2**) were fabricated in the division with an objective of reducing drudgery associated with manual method of harvesting. The brief specifications of walnut harvesters are given

**Table 1** Specifications and fields performance of manually operated Walnut harvester

Particulars	Type I	Type II	Type III	Type IV
Height, cm	609.6	660	610	660
Weight, kg	5.5	5.2	5.2	5.75
No. of fingers	5	3	3	4
Distance between two fingers, cm	2.54	6.35	5.71	4.44
Diameter of fingers, mm	8	8	8	7
Length of the fingers, cm	8.89	11.43	11.43	8.79
Material used	M.S	M.S	M.S	M.S
No. of persons engaged	1	1	1	1
Approx cost, Rs.	175	150	150	150

**Fig. 1** Different type of walnut



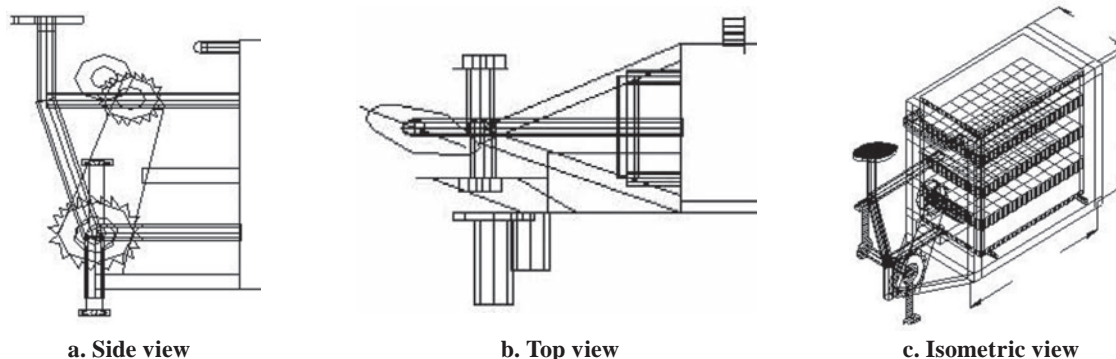
**Fig. 2** Working of walnut harvester



**Fig. 3** Pedal operated walnut grader



**Fig. 3** Views of manually operated walnut grader



in Table 1.

### Walnut Grader

The manually operated walnut grader consisted of mild steel 32 × 32 mm angle iron outer frame. A mild steel 13 mm pipe was provided in front of the grader. The inner frame of the grader assembly consisted of mild steel 25 mm × 25 mm angle iron. Four bearings were provided under the grader assembly for to and fro motion of the grader. The bearings under the grader assembly were connected to each other by 32 mm mild steel round. A sprocket was provided on the side of the grader for converting rotational motion of the pedal into to and fro motion to the grader assembly. A cycle frame along with the standard seat

was provided for holding the weight of the operator (Fig. 3).

Walnuts are available in varied shapes and varieties. The various shapes of walnuts that are predominant are trapezoidal elliptical, oval and round. Walnut varieties differ from one another with respect to size, shape, hardness of the shell. A majority of walnut trees have been propagated from seed and some of the important varieties cultivated in the area are chenova, cheeko and Hartley. The S. K. University of Agricultural Sciences & Technology Kashmir has been propagating two new varieties of walnuts, namely Hamdan and Sulieman, for large scale cultivation to the farming community. The walnut graders worked on the principle of to and

fro motion of the inner frame of the grader. In the grader assembly the rotational motion of the pedal is converted into linear to and fro motion with the help of sprocket attached to the side of the grader. The size of the sieves was fixed on the basis of international standard fixed for walnut sale. The various grades of walnut were walnut super (> 38 mm) Grade I, Walnut special (38-28 mm) Grade II, Commercial (28-22 mm) Grade III and Ex - Grade (< 22m) Grade IV. The feeding of walnuts to the graders was done manually. The walnuts retained in each sieve after grading were collected in a sack or box attached to the grader with hooks. Different views of manually operated graders are given in Fig. 4.

**Table 2** Specifications of manually/motor operated walnut grader

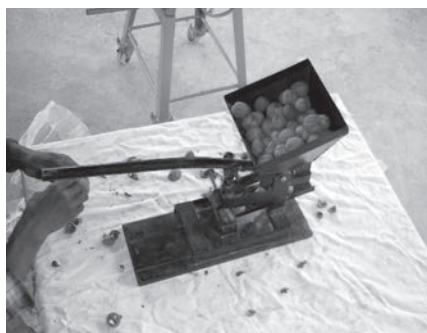
Particulars	Pedal operated grader	Roller type cracker	Impact type cracker
Length, cm	172.2	42	41
Width, cm	50.8	36	15
Height, cm	113.03	80	42
Weight, kg	60	27	2.5
Cost, Rs.	4,500	3,500	450
Material used	MS sheets, flats, angles	MS sheets, flats, angles, bearing, round, flat	MS sheets, flats, angle, Wood, MS round
No. of persons	1	1	1
Sieve sizes/size of nuts, mm	38 32 28 22	All sizes of nuts varying from 22 mm to 55 mm in diameter	All sizes of nuts varying from 22 mm to 42 mm in diameter
Shapes of the holes	Round square	-	-
Capacity, kg/hr	185	20	3.5
Efficiency, %	69	72	83
Breakage, %	Nil	12	5

### Walnut Crackers

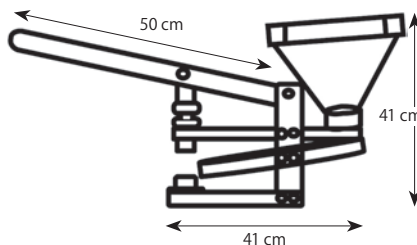
Walnut cracking is done manually. Manual cracking of walnuts is being done even in large industrial units. The manual method of walnut cracking is very cumbersome with large drudgery associated with the breaking of nuts. It has been observed that most of the walnut cracking is done by women with lot of skill and patience for safe recovery of nuts from the shell. The average capacity of walnut cracking manually is 14-18 kg/day, depending upon the efficiency and the skill of the worker.

Two types of walnut crackers namely impact type and roller type were fabricated for increasing the

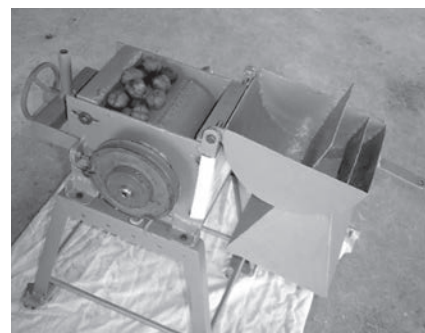
**Fig. 5** Impact type walnut cracker



**Fig. 6** Side view of impact type walnut cracker



**Fig. 7** Roller type walnut cracker





rate and efficiency in walnut breaking. The impact type walnut cracker worked on the principle of impact breaking. Different varieties need different impact force for breaking of the nut. The impact type cracker consists of a hopper of 1.5 kg capacity. A slope of 30° at the bottom of the cracker provides walnuts to the chute for breaking (Fig. 5). The chute is provided with adjustable size of the breaking edge. All sizes of walnut grades Grade I, II, III, IV can be broken in the machine. A side view of Impact type walnut crackers is given in Fig. 6.

The rolling type of walnut cracker consists of a hopper with a capacity of 5 kg (Fig. 7). The principle of working of the cracker is based on the principle of rolling action of a roller against a curved surface (Fig. 8). The clearance between the roller and the curved surface can be adjusted with a movable screw. The curvilinear surface is adjusted according to the size of the walnuts to be broken. A side view of manual roller type cracker is given in (Fig. 9). The roller can be operated with a handle. The specifications and working of pedal operated grader, impact type cracker and roller type nut cracker are given in Table 2.

## Results and Discussions

The average capacity of different fabricated walnut harvesters, Type I, Type II, Type III, Type IV, was 25 kg/hr, 20 kg/hr, 24 kg/hr and 21 kg/hr. The harvesting capacity was much less than manual methods of walnut harvesting of 45 kg/hr. However, use of walnut harvesters tends to reduce the risk associated with walnut harvesting operations as can be observed by large number of accidents taking place during walnut harvesting season. Also, the walnut at inaccessible heights could be easily harvested with the fabricated harvesters.

The average grading capacity of

manually operated grader was 1.85 q/h, with an efficiency of 69 %. The low efficiency in grading was as a result of varied shapes of walnuts like elliptical, oval, round and spherical. Manual grading of walnuts was time consuming with lot of physical work requirement. Normally, in the farmer's fields a group of two or three persons selected walnuts from a big heap and randomly put them in different baskets as per their size. This procedure of grading required a lot of experience and skill. It was observed that 72.7 % saving in cost was obtained as a result of use of manually operated graders. And, time saving of 31.03 % was observed for manually operated grader, than that of the traditional method of grading.

The maximum efficiency of walnut crackers were obtained only after grading of the walnuts had been done. The average capacity of impact type walnut cracker was 3.5 kg/hr with an efficiency of 83 %. The breakages to the kernels were 5 %. The average breaking capacity of roller type walnut cracker was 20 kg/hr with an efficiency of 72 %. The breakages to the kernels were 12 %. Time saving of 52.4 % and 656 % were observed as a result of use of impact type and roller type crackers, respectively.

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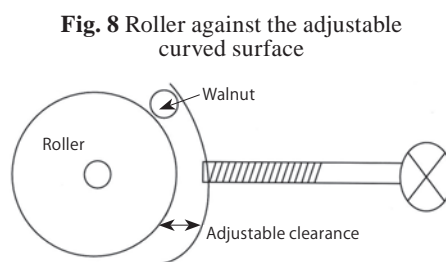
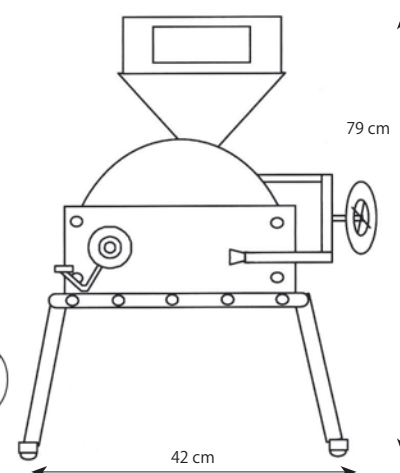


Fig. 8 Roller against the adjustable curved surface

Fig. 9 Side view of roller type nut cracker



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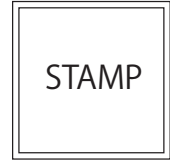
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