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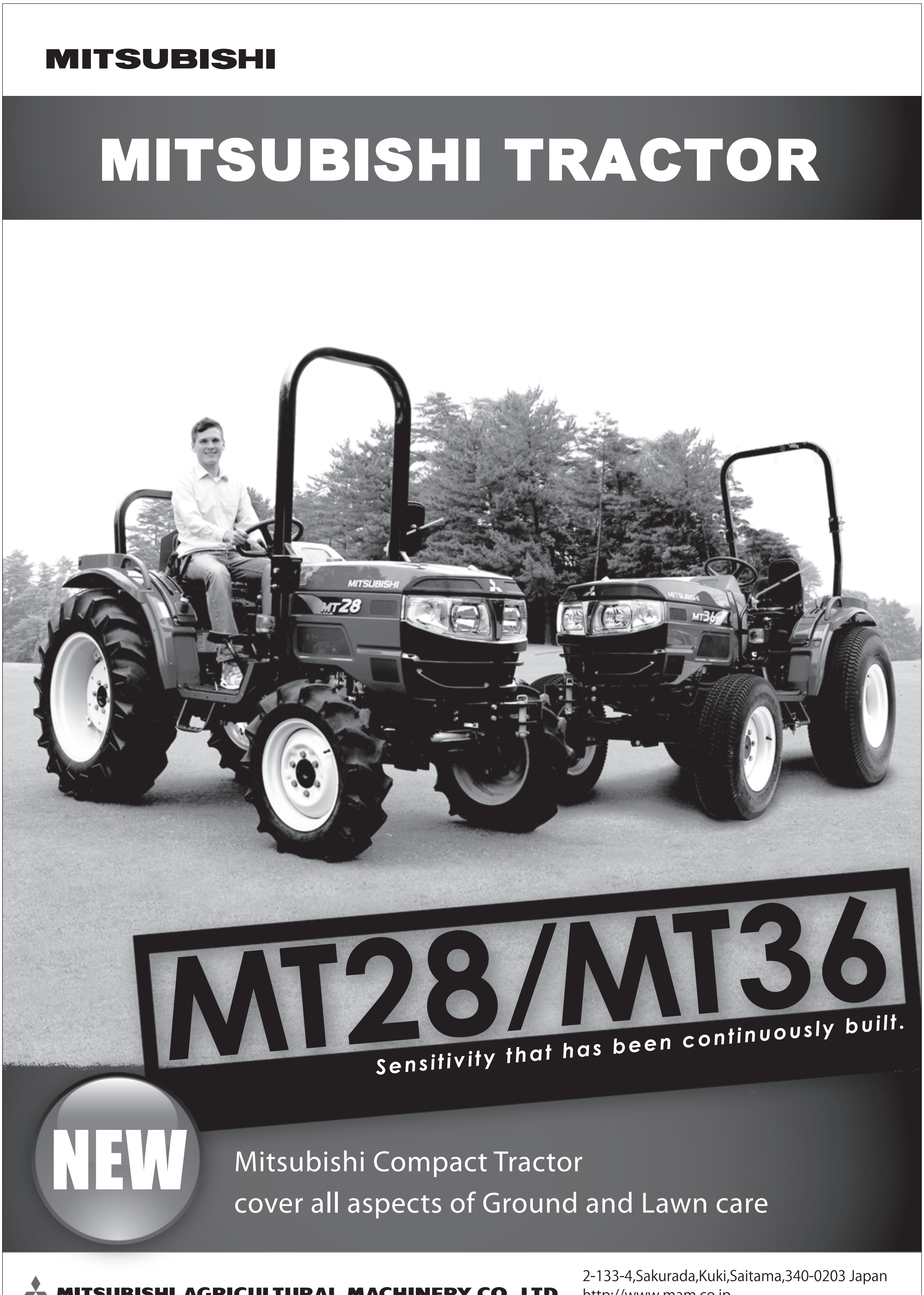
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EDITORIAL

Entering the 21st century, 14th New Year has already come around. According to this year's Food and Agriculture Organization (FAO) of the United Nations , 840 million people have suffered from lack of nourishment in 2012. This number has decreased comparing to 980 million in 1992. Considering the population ratio, 23% of the population suffered from nutrient shortage in 1992 and it has decreased to 14.9% in 2012. Even now due to the poor nutrition, 20 thousand people are starving to death every day.

Writers have written many times that the agricultural land area in the world has limit, and our most important mission is to increase productivity in the limited land even though the population has been increasing. To increase the productivity, timely and precise field work is necessary. To make it possible, agricultural machines take important roles, and increase in agricultural machinery output per capita is one of the solutions for the food problems.

For a long time, we have talked about the situations in the country regarding the agricultural machinery and productivity. However, these days, the concept of urban agriculture has become popular and important. The population has moved to the cities worldwide, and more than half of the world population is now living in the cities; this is happening similarly in the third world counties. The urban population in the world is expected to increase in the future. This phenomenon is the result of the poorer lives in the country living; people move to the cities for richer lives. As a result, the slum areas have developed and expanded, and it has caused the great food problems. We have looked for space and it has become prevalent to engage in farming worldwide. As was expected, it is better to produce and provide food close to the consumers. There are advantages to do so, especially for perishable food such as vegetables. For example, in Tokyo, one of the most crowded cities in Japan, urban farming provides vegetables for 700 thousand people.

Recently, agricultural facilities have improved such as food processing factories, and this technology enables higher efficiency in the small spaces in the cities. Aging of population in the urban area has also increased. The arrangement for the elderly to join in farming in the cities is very important. Importance of agricultural machinery and technology in urban areas is expected to increase. In all circumstances, research and development of new concepts of agricultural machinery are obligatory and necessary. The readers of AMA are the professionals with power to implement and resolve the food problems. I would like to take this opportunity to wish you the best for our future in increasing agricultural productivity with innovative ideas.

Yoshisuke Kishida
Chief Editor

January, 2014

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Up-Gradation and Improvement of Cotton Ginning Machinery

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Abstract

Cotton producing countries are seeking ways and means to boost their exports, essentially to strengthen their economics. Although Pakistan is playing a key role in world cotton trade and production yet facing challenges due to quality and high cost of ginning. One of the major problems faced by the ginning sector is old technology of cotton ginning and lack of standards. Prime objective of this project was to doctor up the ginning machinery and standardize critical parts. A gin stand was design, developed and got fabricated. In the up-graded ginning machinery, output of cotton lint per saw was 6.26 kg/hour comparing 2.77 kg/hour for conventional plant which resultantly doubled the ginning output per gin stand. The improved ginning machinery produced 5 bales per hour, consumed 35 % less electricity by saving 2.81 kW per bale. It also saved 60 % in terms of labour cost. Compact structure of the machine made it safe and user friendly. Development and introduction of fixtures and gauges also facilitated the assembly as well as reduced repair cost and factory down time.

Introduction

Cotton is the largest revenue earning non-food crop produced in the world. Its production and processing provide some or all of the cash income of over 250 million people worldwide, including almost 7 percent of the available labour force in developing countries (Banuri, 1998).

Pakistan is the world's 4th largest producer and 3rd largest consumer of cotton. The largest cotton producing country in the world is China, USA, India and Pakistan. Cotton is the major cash crop and it contributes 8.6 % of the value added in agriculture and 1.8 % of GDP. It is grown on area of 2.6 million ha, producing about 12 million bales of lint per year. Major portion about 90 % of these bales is consumed by the domestic textile and yarn industry (GOP, 2009).

Cotton provides raw material to 450 textile mills, 1236 ginning factories and 5,000 oil mills. Approximately 60 percent of Pakistan's annual export income comes from textile sector. Other industries, such as pharmaceutical, soap, chemical and feed industries also rely on cotton by-products (SMEDA, 2000). Besides this, cotton is an occupation of 1.5 million farming families and provides job to 52 % of labor force. Therefore cotton is known as the life blood of Pakistan economy (GOP, 2009).

Pakistan's cotton quality is the best at the time of picking which is done by hand but fails to preserve its quality during storage, packing, transportation and ginning. It is sold at discounted rates due to its poor quality in international market. Quality of ginned cotton is determined by its grade, trash,

Table 1. Status of Cotton Ginning Factories in Pakistan

Name of Province	No. of Factories	per-centage	Total Number of Gin Stand	Gin Stand with Number of Saws			
				80	90	100	120
Punjab	1063	84	4832	136	2758	1842	96
Sindh & Baluchistan	200	16	913	22	856	35	0
Total	1263	100	5745	158	3614	1877	96

Source: PCGA, 2004

staple length, uniformity ratio, fiber strength, fineness and maturity, presence of neps, colour and micronair. The low volume added products in cotton are foreign matters during packing and transportation. These are leaf, trash, burs, grasses, jute fibers, polyester fibers, polyethylene, hairs, feathers and rope pieces. The range of foreign matters is 5 gm/bale to 35 gm/bale (PCSI, 2002).

There are about 1263 ginning factories in Pakistan most of them are fitted with locally made ginning machinery and whose designs are based upon imported version like Lummus, Centennial and Continental technologies that was used in United State of America during the Year 1960 (Hahn, 2005). All the factories have Saw-gin machines except 6 or 7 units have roller gin machines. There are about 1063 and 200 ginning factories in the Punjab and Sindh Province, respectively. The main cluster of ginning factories about 84 % are in the Punjab Province. The saw-gin machines used are of 80, 90 and 100 saws (Yasin *et al.*, 2004). The detail of ginning factories alongwith number of saw-gin saws are given in the **Table 1**.

The cotton ginning industry in Pakistan is of old technology, inefficient and high energy consuming. In USA saw gin stand capacity has been static at 15 to 20 bales per hour and none of the ginning equipment manufacturers expect to increase capacity in the near future (Valco, 2004). Comparing USA gin stand capacity in Pakistan it is only 2 bales per hour which is very low (SMEDA, 2005).

There are several factors involved in the ginning rate and ginning energy. Bechere *et al.*, 2011 found that large amount of genetic variability for ginning rates and ginning energy requirements among the tested genotypes. They further reported that ginning rate appeared to be related to desirable ginning performances such as higher fibers seed-1, higher lint percent, higher boll weight, and higher maturity ratio.

Typically, the capacity in the gin plant is limited by some other component such as cleaning and drying equipment or the bale press. Some ginning factories are just adding more gin stands to gain the added capacity (Valco, 2004).

In older plants, ginners are looking at new technology to improve efficiency and capacity. One concern is the size or geometry of cottonseed. Smaller cottonseed size will continue to be a challenge for ginners. Seed size also determines the rib gap and increase of rib gap plays key role in increasing the gin stand output/capacity.

In Pakistan specific standards and technical manuals are not available for the ginning machines operation, adjustment and maintenance. Research work on improvement of its design and work efficiency has not been conducted to improve this sector. The local manufacturers of ginning machinery are semi-skilled mechanics without any professional skill and training. They failed to manufacture correct saw-gin machines and missed/ changed many critical specifications during fabrication of Saw-gin machine (Yasin *et al.*, 2006).

Ginning industry is a seasonal business and it only run during the months of October to March starting from south region to central part of the country. It is established fact that ginners annually renovate ginning equipment, make adjustments to provide the good quality cotton. This renovation takes at least two months every year before start of ginning season and this is called down time. Annual repair is time consuming, labour intensive and operational slowdowns are very costly. It must be reduced to improve the efficiency and reduce ginning costs.

Safety and health of workers in the cotton ginning industries is also an important concern.Workers have to operate under extremely unprotected conditions. Although there is no formal data available in Pakistan related to injuries in cotton factories yet accidents due to unsafe working condition in cotton ginning factories are increasing. Young labourers injure their limbs, mainly the working arm/hand or leg and render partly or fully disable and loose earning ability.

In the conventional ginning machines, several safety issues have been identified. Major accidents happen during annual repair as well as during operation of the factories. Non availability of formal jigs and fixtures force the technicians to take risk even for very sensitive jobs. Conventionally bricks are used instead of solid fixture for placing saws on the saw shaft.

Pulleys and belt running on high speed are mostly open while work force uses loose cloth in the factory premises. Loading of the saw shaft weighing above 170 kg with sharpened saws in the gin stand has also been done manually. Probability of slippage or failure in lifting during placing of shaft also caused several accidents. **Fig. 1** shows the prominent chances of injury.

In addition to above non-operational dust settling system and floating fibres in the factory area is not only a worry for the factory worker but also serious environmental risk for the neighbourhood also. Inhaling of cotton fibres leads to the serious disease of Byssinosis.

Kobayashi *et al.* (2003) reported that cotton fibre inhalation may be related to a granulomatous reaction and peribronchial fibrosis in the lungs. Their findings support the possibility that, like inorganic dust, organic dust can also cause pneumoconiosis.

Straight teeth ginning saws cause seizuring during ginning and increase short fiber which directly affects the quality of cotton lint. Davenel Yannick (2002) reported that the existing saw-gin used in Pakistan were out-dated and did not gin cotton in good conditions. He suggested improving the existing saw-gins and other machines used in the ginning factories. He further reported that development of a new saw gin was complicated and necessitated important studies before design and fabrication.

Government of Pakistan, Ministry of Industries, Production & Special Initiatives constituted a Task Force during the year 2005 to upgrade and standardize the ginning machinery for production of export quality ginned cotton at minimum cost (EDB, 2005). The objective of the Task Force was to develop and standardize gin stand, and to introduce jigs, fixtures and inspection gauges.

The cotton ginning in Pakistan is facing two major problems i.e. poor quality of ginning and high cost of ginning. The improvement in ginning quality and reduction in cost of ginning can be achieved through introduction of improved ginning technology, practicing of proper maintenance schedule, enhancement of technical skills of the operational staff, incentives to growers for clean cotton picking, transportation and some regulatory measures to enforce quality standards (Yasin, 2007). There is a need for improvement in ginning technology through up-gradation of gin stand, pre-cleaning, pre-opening machinery and feed control system. Therefore the study was planned with the objectives to modify & improve existing ginning machinery and to standardize various parts & components fitted in gin-stand to facilitate interchangeability of these parts & components.

Material and Methods

The progressive ginning factory i.e. Bismillah cotton ginning factory, Bahawalpur was selected for improvement and development work. The design modification work was done in the gin stand mainframe, saw-gin, ginning saw, ginning ribs and spacer. The saws shaft speed was improved and sharpening of ginning saws procedure was also improved. The inspection gauges and fixtures were designed, fabricated and introduced during fitting of the machines.

In the first phase of the project, critical areas for improvement were identified. Modification in the geometry of parts and machine system was done in 2nd phase. Similarly 3rd phase was testing and evaluation of the modern gin stand. Safety of the factory work force was given due importance.

Design of ginning ribs, huller ribs, spacers, saws rib gap were identified as pivotal factors for consideration. Geometry and diameter of cotton seed for different varieties was tested to determine the gap between ribs at ginning point. Gravity moting system was introduced for effective removal of motes with air jet of lint doffing. Mote board was wide enough to protect lint during motes removal. Consequently designing of ginning ribs, huller ribs and spacer was done to match other parameters.

The upgraded and improved gin stand was tested to check it performance. The mechanical and performance parameters measured were saws shaft speed, air suction velocity, lint output, energy saving, labour saving and bales per hour per gin stand. The lint characteristics were also measured such as staple length, strength, trash content etc.

Operational and mechanical parameters were tested in the factory while lint parameters were got evaluated with the help of Pakistan Cotton Standard Institute.

Fig. 1 Conventional method for insertion of spacers and saws on saw shaft and placing saw shaft in the gin stand

Conventional gin stand | Improved gin stand

During factory testing anemometer was used for air velocity, tachometer for rotational speeds, sound level meter for measuring level of sound and wet bulb hygrometer for ambient temperature and humidity in air.

The conventional and improved gin stands were tested by keeping most of the test conditions same. In order to compare the performance of newly introduced FEC system in the improved gin stand, one pre-cleaner was by-passed while conventional gin stand was tested with regular set up.

The seed cotton mixed variety used during testing was of grade three at heap moisture level 8-10 %. The moisture level at gin stand was 7-8 % with trash content of 20-25 %. The environmental conditions were 22-28 ºC ambient temperature and 29-42 % relative humidity.

In order to compare the results and maintain homogeneous conditions, the same heap of seed cotton was used for the testing of improved and conventional systems.

Results and Discussions

The improvement work done in the cotton ginning machinery was design of gin stand which included main frame, incorporation of feeder extractor cleaner (FEC), increased number of ginning saw, design of ginning saw, standardization of ginning rib, spacer and improvement of huller rib. Easy repair, adjustment and safety features were also incorporated in the gin stand. The inspection gauges, jigs and fixtures were designed and manufactured for inspection, fabrication and fitting of gin stand parts and components.

The gin-stand main frame was designed to achieve structural stability, ease in repair, adjustment and replacement of parts. The idea of modular design was adopted alongwith covers of different components. Electrical controls were provided adjacent to gin stand instead for in operation. **Fig. 2** shows comparison of conventional and improved gin stand with all safety features.

The important components of gin-stand i.e. ginning saw, ginning rib, spacer and channel saw were designed to achieve desired objective of good quality ginning. The gin stand rollers, spikes, grids and covers were modified in term of diameters, lengths, angles and clearances.

Compatibility of the feeding system with modified gin stand was a challenge, so length feeder was modified and feeding was made variable to match the capacity of the gin stand. In order to preserve good quality of lint some ginners arrange manual cleaning. Manual cleaning is not only a slow process but it also very expansive. So mostly has to pass from different mechanical cleaners and excessive beating directly affect its quality.

Final cleaning of cotton is done by a cleaner built-in with gin stand. In this pre-cleaner, beating drums are aligned horizontally. Beating spikes are randomly welded on the metallic sheet metallic wire net is fixed on the concave. It is generally assumed that abrasive action of spikes with straight roller against net remove small contaminations without affecting quality of lint. Test results showed poor cleaning and bad affect on lint as well.

Therefore Feeder Extractor Cleaning (FEC) system was added in the new gin stand. In FEC the cleaning drums have solid 5 mm thick metal plate instead thin sheet. Drums are aligned at a certain angle and upward motion of seed cotton in the inclined grid arrangement and then further cleaning with channel saw gently removes small particles as well as seed cotton against grid bars and impact action of cotton against grid bars removes trashes. **Fig. 3** sketches the internal design of horizontal and inclined drum system. The sizes of FEC rollers, spikes and grids were improved. In order to increase ginning capacity and reduce labour, numbers of saws were increased from 90 to 124. Gin stand with increased saw (124 saws) enhance its efficiency and work capacity.

The pitch and shape of the saw teeth are important in maintaining capacity and ginning quality. The cutting of the teeth profile shape and sharpening of the top part of the teeth was very important to achieve maximum length of lint. To ensure good ginning, the teeth should pass through the ribs at a proper angle.

Fig. 2 Conventional and improved gin stand

Conventional gin stand

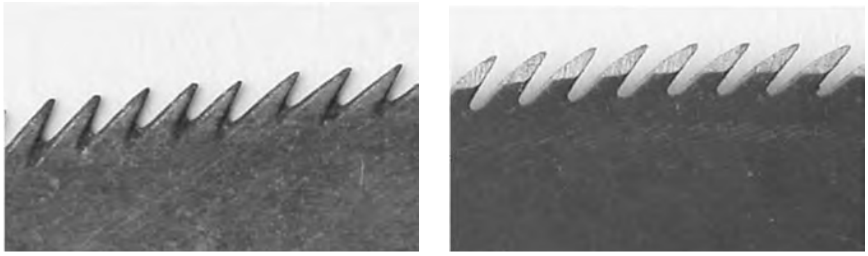
Improved gin stand

The leading edge of the tooth should be parallel with the rib, or the point of the tooth should enter the ginning rib slightly ahead of the throat. In other case, if the throat of the tooth enters the ribs ahead of the point, the resulting cutting action will reduce capacity and break lint and may cause choking at the top of the ginning ribs.

Quantity of lint that a saw removed depended on cotton cleanness and metallurgical properties of the saw. Rough cotton caused more wear than clean cotton. The saw ensured the accuracy of ginning and feeding function. It was observed that reduction in saw diameter reduced feeding rates, increased neps ratio in the lint and reduced production. The ginning saw 12″ inch diameter having 264 to 282 teeth was manufactured from alloy steel metal having self sharpening property and was heat treated to improve its performance and durability.

The saw working angle was 37 to 42º according to the curve of ribs. The thickness of the saw and teeth was maintained 0.92 mm and 0.98 mm, respectively. The top point of saw was made 0.28 mm thick and symmetrical to take the lint correctly. The ginning saws should be projected 45-50 mm above the ribs to have a quality ginning and good output. The improved saw was designed with curved teeth and curved root of teeth (**Fig. 4**).

Fig. 4 Conventional versus improved ginning saws

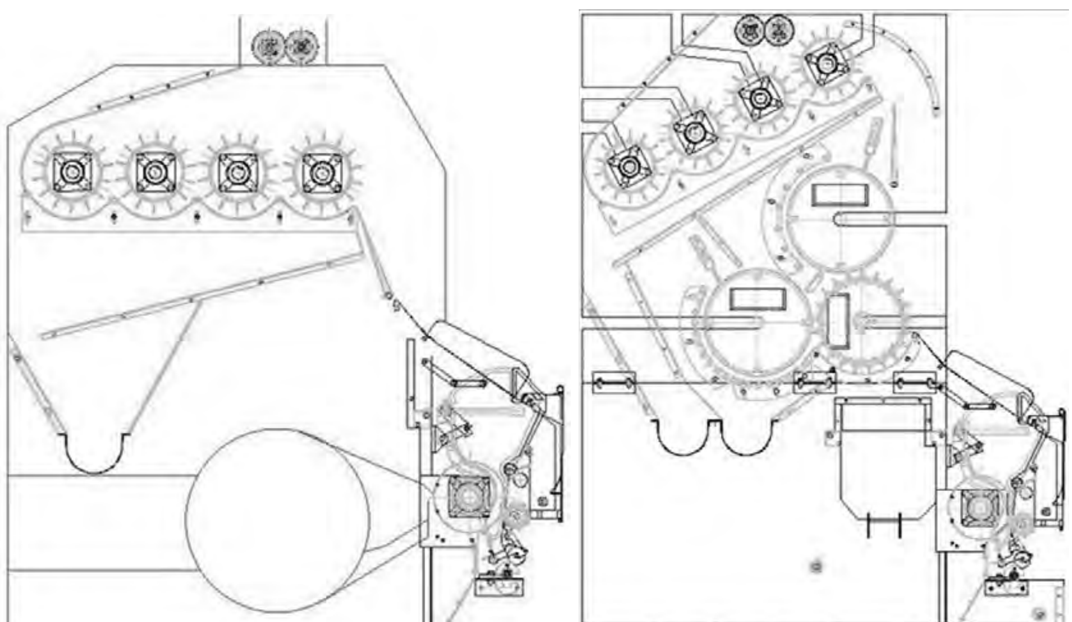


The sharpening of saws method used locally damaged the shape of the teeth. The saws were normally re-sharpened with triangular filer that made some lateral V-grooves on each side in the bottom of the teeth. In the bottom of the groove an angle edge formed that cut the lint. The filer re-sharpening also made a cutting angle in the front part of the teeth, the place normally helps pull the lint through the ribs and there were chances to damage the lint. The other problem of re- sharpening the saws was that the front angle in the rib was always changing because of two main reasons. Firstly the re-sharpening always changes the angle; secondly the diameter of the saw was reduced. The ginning point was lowered down and created a difference between ribs and saw teeth front. The saws should be replaced instead of re-sharpening.

The ginning ribs should be correctly mounted on the frame therefore, it is essential to group them per lot with same shape and dimension before mounting. The standardized ribs are easy to install in the ginning frame. This will help to maintain accurate gap to avoid bad ginning.

The ginning ribs help stop seeds to move with saws during fiber extraction process. Ribs space is very critical as it determine the ginning output. Conventionally it was being adjusted between 1.8-2 mm and it depends on the size of cotton seed. Size of cotton seed was observed for four different varieties of seed cotton. The largest diameter was 7 mm while the smallest was 3.02 mm. All the neps were found smaller than the minimum size of the

Fig. 3 Comparison of internal structure of gin stand



Conventional saw Improved saw

seed. Therefore it was found safe to decide 2.75 mm gap between ribs at ginning point to separate seed. Foot width of ginning ribs and width of spacer was determined accordingly.

The ginning rib was designed to have uniform width, more wear resistance at ginning point. The width of rib at ginning point was kept 14 mm. **Fig. 5** shows the comparison of improved and conventional ribs. The gap between saw and ribs was maintained about. The gap between ribs was maintained 2.75-2.8 mm for safe movement of saws of thickness about 0.92-0.94 mm.

Increased rib gap facilitated the gentle movement of lint from space and also saved ribs as well as saws from abrasive action due narrow space during rotation of saw shaft.

Spacers protect saws from deflection also maintain gap between ginning saws for their safe rotation in the middle of ribs. Therefore specifications of the spacer were improved and standardized. The improved spacers were fabricated with uniform width of 15.58 mm. It helped strengthened the saws and avoided its deflection. The conventional spacer was of non uniform width and created deflection in the saw.

The inspection gauges such as rib gauge, spacer gauge and saw projection gauge were designed and fabricated to use during the fitting, inspection and adjustment of these parts. Rib gauges help inspect the width of ribs at feet and also to adjust the gap between ribs. Saw projection gauge is having variable length of spindle facilitates in fixing uniform projection of all the saws above ribs in one gin stand.

These gauges provided ease and less time in parts replacement. The development of gauges helped incorporate standardization in the design of the machine parts. Fixtures for inspection of contour of ribs were also designed to use for fitting of various parts of the gin-stand. The inspection gauges and a fixture for insertion of ginning saws on saw shaft are shown in the **Fig. 6**.

The improved gin stand was tested in comparison with conventional gin stand. It was observed that saw shaft speed was different in different ginning machines. The ginners generally increase the saws shaft speed to increase the ginning output. The saws shaft speeds were measured 750 to 900 rpm for conventional gin stands. Seed damage at high speed of saw shaft was in the wide range of 1 to 2.3 percent.

High speed saw shaft was directly affecting the quality of lint while reduction in saw shaft speed not only improved the ginning quality but also decreased the damaged seeds. Up graded gin stand was tested at different speeds of saw shaft and 650 rpm was found appropriate. Only 0.25 % seeds were found damaged when saw shaft was operated at the speed of 650 rpm and ginning output was still reasonable. Although no specific test was carried out for floating fiber yet reduction in floating fibers with upgraded gin stand was prominent.

Environment in most of the running cotton factories was very bad and giving the impression of cloud due to floating fibers. Textile mills also face trouble due to short fiber in lint. This result agrees with the findings of the following scientists. Griffin (1977, 1979) found that short fiber increased as saw shaft speed increased. Mangialardi *et al.* 1988 determined that increasing the speed of shaft increases the ginning rate while it increases the uster yarn imperfections. Seed damage can also be result from increasing the speed of saw shaft. The mechanical and performance parameters of gin stands were measured as given in the **Table 2**.

In order the meet the higher ginning capacity the air suction velocity was adjusted at 51 m/s for improved gin stand as compared to 45 m/s for conventional gin stand. The air suction velocity was higher in improved gin stand and gave better collection of lint.

Noise level in the factories is important environmental concern. Chronic exposure to ambient noise would interact with job complexity to affect blood pressure levels over time. Melamed *et al.*, 2001 found that logistic regression results indicated that the interaction of noise exposure levels (high/low) and job complexity (high/low) was associated with increased risk for elevated

Fig. 5 Improved versus conventional ginning ribs

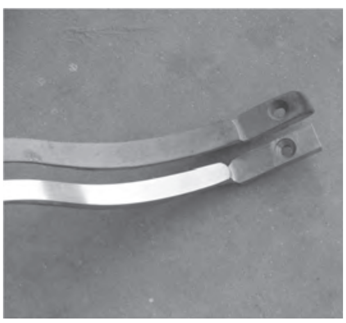
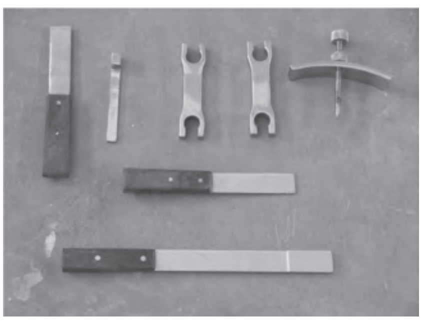


Fig. 6 Inspection gauges used for fitting, inspection and adjustment of ginning machines and saw placing fixture



Inspection gauges

Fixture for insertion of saws

Table 2 Mechanical and Performance Parameters of Conventional and Improved Gin Stands

Description	Conventional Gin Stand	Improved Gin Stand
Speed of saws shaft (rpm)	700-900	650
Air suction velocity (m/s)	45	51
Sound level at gin stand (dB)	100-102	87-90
Saws on gin stand (Nos.)	100	124
Output of lint per saw (kg/hour)	2.77	6.26
Output of lint per gin stand (kg/hour)	277	776.2
Output of lint per 2 gin stand (kg/hour)	554	1552
Bales per gin sand (Nos./hour)	2	5
Current consumed per gin stand (Amp)	22	40
Current consumed per saw per kg of lint (Amp)	0.079	0.051
Labour required for gin stand	5	2
Labour saving with improved gin stand (%)	-	60 %
Current saving with improved gin stand (%)	-	35 %
Energy saving with improved gin stand (kW/bale)	-	2.81

Table 3 Comparison of lint Characteristics of Ginned Seed Cotton

Description		Conventional Gin Stand	Improved Gin Stand
Staple (inch)		1.3	1.3
Strength (G / Tax)		26.5	27.0
Uniformity		47.1	81.7
Elongation		6.9	6.9
Trash (%)		6.6	6.3
Micronair		3.8	3.8
Colour	Rd.	73.4	73.3
	+ b	10.1	10.4

blood pressure.

In Japan, governmental guidelines recommend the provision of full band auditory examinations for workers exposed to high levels of noise; the corresponding workplaces, where noise levels are expected to exceed 85 dB, are specified in the guidelines (Mizoue *et al.*, 2003). Therefore noise level was also tested for this machine. The sound level of improved gin stand was observed lower 88.5 dB an average than conventional gin stand that measured 100 dB.

This sound level was recorded during ginning process and includes noise produced by all operational machines installed in the shed. Typically, suction fans installed in the ginning shed were one of the major sources of noise. Noise 88.5 dB is slightly above the international work and safety standards and it can further be reduced by moving suction fan out of the shed walls.

The lint characteristics were also checked as given in the **Table 3**. Beyond the fact that inclined cleaner was by-passed for the testing of upgraded gin stand still trash contents in the lint received from improved gin stand were less than the trash from conventional gin stand. This finding suggests that up graded gin stand can safely by pass one precleaner. The staple length, micronair and elongation were found comparable in both the gin stands, while strength, uniformity and trash content were measured different. The strength of lint was found higher 27 G/Tex for improved gin stand. Similarly uniformity of lint improved by about 70 % from 47.1 in conventional to 81.7 in up graded gin stand.

Improved gin stand removed 14.5 % more trash than the conventional one.

The improvement in seed cotton cleaning and opening machinery prepared seed cotton well for opening, helped removal of trash and gave regular seed cotton flow to saw-gin for quality ginning. The operation of conventional and improved gin stand is demonstrated in the **Fig. 7**.

The improved gin stand gave 5 bales per hour per gin stand as compared to 2 bales per hour per gin stand of conventional gin stand. The lint output per saw was determined 6.26 kg per hour and 2.77 kg per hour for improved and conventional gin stand, respectively. The improved gin stand consumed 2.21 KW per bale which is 35 % less than conventional gin stand. The labour saving was 60 % less for improved gin stand because 2 workers were required for improved gin stand as compared to 5 workers for conventional gin stand.

Conclusions

In addition to other benefits, the up-graded and improved cotton ginning machinery gave a higher output, lower energy consumption and lower man hours as compared to conventional ginning machinery.

The standardization of critical parts and improvement in main frame of gin stand reduced 75 % of its parts assembly time. It also gave structure stability, ease in repair/maintenance, safety in operation and environmental as well as user friendly. In the up-graded ginning machinery, output of cotton lint per saw was 6.26 kg/hour comparing 2.77 kg/hour for conventional plant which resultantly doubled the ginning output per gin stand. The improved ginning machinery produced 5 bales per hour, consumed 35 % less electricity by saving 2.81 kW per bale. It also saved 60 % in terms of labour cost. Beyond increase in the ginning out put it preserved the lint quality. The improved gin stand has reduced sound level from 101 dB to 88 dB. Sound level in the ginning shed can further be reduced by moving the suction fan out of the shed.

The improved gin stand gave good cleaning efficiency due to good repartition of seed cotton flow on all the width of the machine and reduced the thickness of the sheet of seed cotton to have regular seed cotton flow.

Development and introduction of fixtures and gauges also facilitated the assembly as well as reduced repair cost and factory down time.

It is strongly recommended to standardize all other parts of the ginning machines for continuous improvement in the efficiency and quality of ginning.

REFERENCES

Banuri, Tariq. 1998. Pakistan: Environmental Impact of Cotton Production and Trade. Paper prepared for UNEP project on trade and environment. http://www.iisd.org/TKN/pdf/pk_banuri.pdf accessed on July 21, 2011.

Bechere, Efrem, J. Clif Boykin, and W. R. Meredith. 2011. Breeding and genetics Evaluation of Cotton Genotypes for Ginning Energy and Ginning Rate. The Journal of Cotton Science 15: 11-21.

Davenal, Yannick. 2002. Mission Report I & II of International Experts for Improving Fiber Quality in Pakistan. Digest –SMEDA, Lahore, Pakistan.

EDB. 2005. Formulation of Task Force for Up-gradation and Improvement of Ginning Industry of Pakistan. Ministry of Industries, Production and Special Initiatives, Government of Pakistan. EDB-Report.

Government of Pakistan. 2009. Agricultural Statistics of Pakistan, Ministry of Food, Agriculture, Islamabad.

Government of Pakistan. 2009. Economic Survey of Pakistan. Ministry of Finance, Economic Advisory Wing, Islamabad.

Griffin, A. C. Jr. 1977. Quality control with high capacity gin stands. Cotton Ginners Journal and year book 45: 25, 28-29.

Griffin, A. C. Jr. 1979. High speed ginning and fiber damage. Textile Research Journal 49: 123-126.

Hahn, J. N. 2005. Pakistani Cotton Fiber Production. Study, Analysis and Recommendations. SMEDA report Ministry of Industries and Production Government of Pakistan.

Kobayashi, H., S. Kanoh, K. Motoyoshi, and S. Aida. 2003. Case report, Thorax 2004; 59: 1095-1097. doi: 10.1136/thx.2003.014027 http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1746888/pdf/v059p01095.pdf accessed on July 30, 2011.

Mangialardi, G. J. Jr., J. D. Bargeron, III, and S. T. Rayburn, Jr. 1988. Gin stand feed rate effects on cotton quality. Transactions of ASAE 31: 1844-1850, 1894.

Melamed, Samuel, Yitzhak Fried, and Paul Froom. 2001. The Interactive Effect of Chronic Exposure to Noise and Job. Journal of Occupational Health Psychology. Vol. 6, No. 3, 182-195.

Mizoue, T., T. Miyamoto, T. Shimizu. 2003. M Combined effect of smoking and occupational exposure to noise on hearing loss in steel factory workers. Occup Environ Med 2003; 60: 56-59.

PCGA. 2004. Pakistan Cotton Ginners Associate year book.

PCSI. 2002. Cotton Ginning Standards. Pakistan Cotton Standard Institutes, Ministry of Industries and Production, Government of Pakistan.

SMEDA. 2000. Cotton in Pakistan. Ministry of Industries and Production, Government of Pakistan.

SMEDA. 2005. Cluster profile, cotton ginning cluster, Rahim Yar Khan.

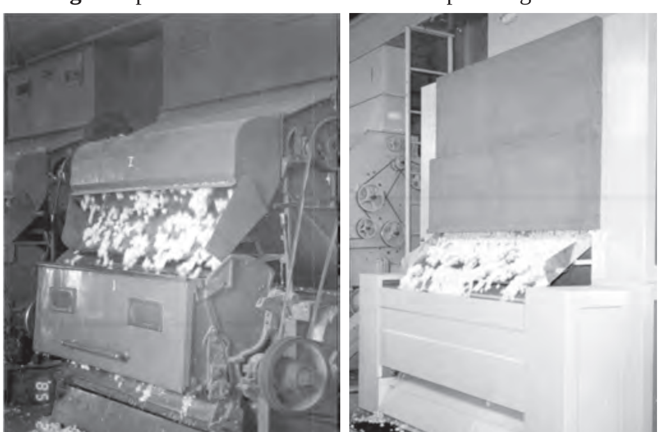
Valco Thomas D. 2004. “Cotton Ginning Trends”. USDA –ARS, National Cotton Ginners Association. Proceedings of 2004 beltwide cotton conference, San Antonio, TX, January 5-9.

Yasin, M. and A. A. Khan. 2004. Field Survey Report about Cotton Ginning Industries in Pakistan. AMRI, Multan.

Yasin, M., A. A. Khan, and M. A. Majeed. 2006. Development and Testing of Standardized Gin Stand. AMRI Report, Department of Agriculture, Government of the Punjab, Multan.

Yasin, Muhammad. 2007. A case study report for up-gradation of Bismillah Cotton Ginning Factory, Bahawalpur, 11th In-service Training Course for Senior Executives. Government Engineering Academy, Punjab, Lahore.

Fig. 7 Operation of conventional and improved gin stand



Conventional   Improved

Performance Evaluation of Different Models of Power Weeders for Pulse Crop Cultivation

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Abstract

The arduous operation of weeding is usually performed manually with the use of traditional hand tools in upright posture, inducing back pain for majority of labours. Weeding is the one of the labour intensive and tedious operation in pulse cultivation. This situation necessitates the introduction of suitable power weeders for pulse cultivation. With this objective to select the suitable power weeder for pulse cultivation a study was conducted at TNAU fields with 3 models of commercially available power weeders (Model A, B and C). In this case, to suit the power weeder the crop geometry was modified with 60 × 10 cm in pulse cultivation. The three models were compared with conventional method of hand weeding. The working width of the power weeders were 60 cm, 60 cm and 30 cm respectively for Model A, B and C. Manual weeding using hand hoe registered maximum weeding efficiency of 83.10 % (wet basis) and 82.5 % (dry basis). The weeding efficiency of Model A was 74.10 % (wet basis) and 73.45 % (dry basis), Model B recorded 63.49 % (wet basis) and 64.15 % (dry basis) and Model C recorded lowest weeding efficiency of 43.43 % (wet basis) and 43.13 % (dry basis). The saving in cost of weeding operation with three models when compared to manual weeding were 75.8, 72.5 and 54.8 % respectively for Models A, B and C. The saving in time of weeding operation using with the three models when compared to the manual weeding was 95.8, 94.6 and 89.8 % respectively for Models A, B and C.

Introduction

Pulse crops are grown on large scale in almost all tropical and subtropical countries of the world. The major pulse producing counties are India, china, Canada, Brazil, Australia, Nigeria, France, Myanmar, USA, Turkey, and Mexico. Among these, India occupies first position in acreage and production. The important pulse crops grown in India during Kharif are green gram, black gram, pigeon pea, horse gram and cow pea and during Rabi season chick pea, lentil, fababean and dry pea.

The area and production of pulses in India in 2005-06 was 22.39 million ha and 13.39 million tonnes, with a yield of 598 kg/ha. India is the key player with 25 % share in the global pulses basket. The area under pulses, production and productivity of total pulses in Tamil Nadu in 2005-06 was 0.53 million ha and 0.18 million tonnes and 337 kg/ha respectively. Tamil Nadu accounts for about 3 % of the total area under pulses and 2.5 % of total production in India.

The productivity of farms depends greatly on the availability and judicious use of farm power in pulse production. Agricultural machines increase productivity of pulse crop and reduce non availability of labours by meeting timeliness of farm operations and increase work output per unit time.

One third of the cost of cultivation is spent on weeding alone when carried out with manual labour. The arduous operation of weeding is usually performed manually with the use of traditional hand tools in upright posture, inducing back pain for majority of labours. Weeding is the one of the labour intensive and tedious operation in pulse cultivation. This situation necessitates the introduction of suitable power weeders for pulse cultivation.

Review of Literature

Hand weeding with or without

hoes can be an important and effective means of controlling weeds within the planted row if there is conducive soil moisture. The physiological demand in using weeders was relatively higher than that in manual weeding. However, the efficiency of the work in terms of area covered was significantly better with the weeder than with manual weeding. The energy demand in manual weeding is only about 27 % whereas for weeding with different weeders, the energy goes up to 56 %. The strain was relatively less in case of wheel hoe type weeder (Rajasekar, 2002).

According to Pullen and Cowell (1997), cutting action of the blade hoe is used most efficiently when operated at shallow depth and increasing the working depth does little to improve weed kill but a higher forward speed increases soil covering of weeds and may reduce their survival.

Padole (2007) reported that rotary power weeder works better in respect of working depth (5.67 cm) which is 16.67 % more than bullock drawn blade. Goel *et al.* (2008) reported that the plant damage increased with decrease in moisture content below 11.63 % and this may be due to the reason that with decrease in moisture content soil hardness increased and as a result weeder could not penetrate to desired depth and sometimes skid over hard surface and strikes the plant. Higher percentage of plant damage at 13.52 % soil moisture content was due to more softness of soil which allowed higher penetration of weeders inside soil surface that cause root damage and uprooting of some plants.

Rangasamy *et al.* (1993) evaluated the performance of power weeder and the field capacity of the weeder was 0.04 ha hr^{-1} with weeding efficiency of 93 for removing shallow rooted weeds and the cost of operation with power weeder amounted to Rs. 250 as against

Rs. 490 by dryland weeders and Rs. 720 by manual weeding with hand hoe per hectare. The saving in cost and time amounted to be 65 % and 93 %, respectively.

Material and Methods

With this objective to select the suitable power weeder for pulse cultivation a study was conducted at TNAU fields with 3 models of commercially available power weeders (Model A, B and C). In this case, to suit the power weeder the crop geometry was modified with 60 × 10 cm in pulse cultivation. The three models were compared with conventional method of hand weeding. Specifications of the three models of the power weeder are given in **Table 1**. The operational view of power weeders are shown in **Fig. 1**.

The selected three weeders were used for weeding the pulse crop and its performances were compared with the conventional method of weeding. In the conventional method of weeding a pulse crop is performed by women labourers using a hand hoe.

The treatments selected for the investigation were:

T_1: Conventional (Manual weeding)

T_2: Operation with self propelled power weeder Model A

T_3: Operation with self propelled power weeder Model B

T_4: Operation with self propelled power weeder Model C

The weeders were evaluated for its performance in terms of weeding efficiency (wet and dry basis), depth of operation and percentage of plant damage. The moisture content of the soils during the evaluation was 15.28 % on dry basis.

The cost of weeding using the different models of power weeder was compared with the manual weeding method.

Table 1 Specification of the power weeders

Particulars	Model A	Model B	Model C
Power, hp	5.5	4	1.6
Power source	Four stroke petrol engine	Four stroke diesel engine	Two stroke petrol engine
Width of operation, mm	600 (Adjustable up to 800 mm)	450 mm	300 mm

Fig. 1 Operational view of the power weeders Model A, B and C

Table 2 Results of the performance evaluation of the power weeders in pulse crop

Particulars	Manual	Model A	Model B	Model C
Wet weight of weeds collected, gm/m^2	436.70	400.40	305.30	184.83
Wet weight of weeds left out in the filed, gm/m^2	88.80	140.00	175.50	240.77
Total wet weight of weeds, gm/m^2	525.50	540.40	480.80	425.60
Weeding efficiency(wet basis)	85.1	74.1	63.49	45.43
Dry weight of weeds collected , gm/m^2	237.27	155.78	119.64	71.28
Dry weight of weeds left out in the filed, gm/m^2	50.33	56.32	66.86	93.98
Total dry weight of weeds, gm/m^2	287.60	212.10	186.50	165.26
Weeding efficiency(dry basis)	82.5	73.45	64.15	43.13
No. of plants for 30 m long	109	104	98	118
No. of damaged plants	2	10	11	5
Percentage of damage	0.18	9.62	11.2	4.2
Depth of operation, mm	38	62	58	35

Results and Discussions

The performance evaluation results of the different models of the power weeder is shown **Table 2**.

The weeding efficiency for all the models is shown in **Fig. 2** and **Fig. 3**. It is observed that there was no significant variation between the weeding efficiency on wet basis and dry basis in all the treatments. Among the treatments Manual method registered the maximum efficiency of 83.1 % (wet basis) and 82.5 % (dry basis). The efficiency of model A and Model B are comparable. Model C had a lowest efficiency of 43.43 % (wet basis) and 43.13 % (dry basis).

The depth of operation in weeding for all the treatments are shown in **Fig. 4**. It was in inferred that the depth of operation was highest in Model A operation (6.2 cm) followed by Model B (5.8 cm). Owing to this maximum depth of operation the weeds were completely uprooted and the weight of the weeds collected per unit area was also maximum in Models A and B as seen from the

Fig. 2 weeding efficiency in wet basis

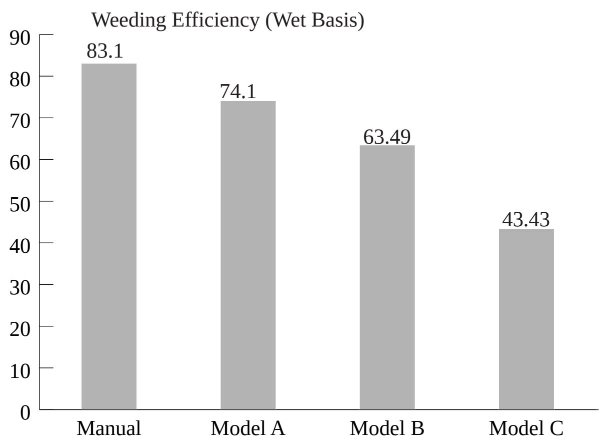


Fig. 3 weeding efficiency in dry basis

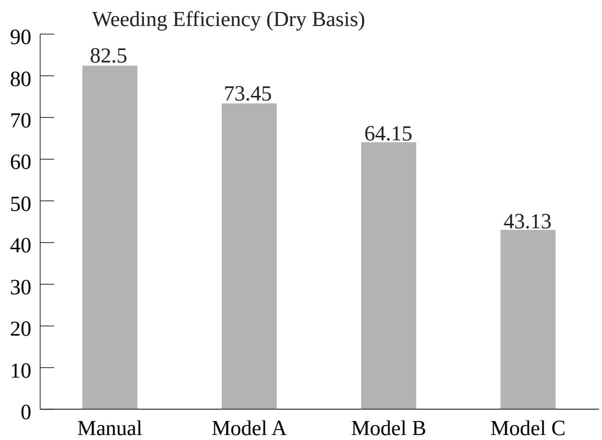


Fig. 4 Depth of operation of weeders

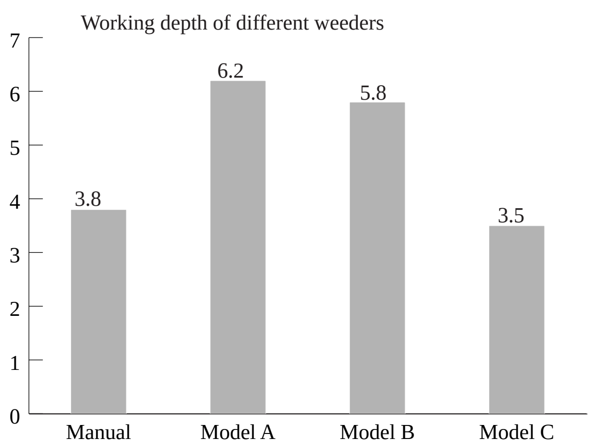


Fig. 5 Percentage of plant damage

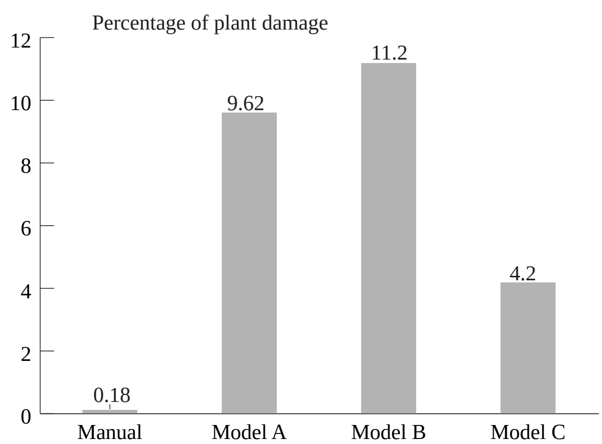


Table 3 Results of the evaluation of the power weeders in pulse crop

Particulars	Manual	Model A	Model B	Model C
Length of the field, m	-	50	50	50
Width of operation, m	-	0.600	0.450	0.300
Time taken to travel 50 m, sec	-	125.4	135.5	160.4
Forward speed, km/hr	-	1.43	1.32	1.12
Theoretical field capacity, ha/day	-	0.686	0.475	0.268
Size of the filed , m^2		50 × 15 = 750		
Time taken to complete 750 m^2, min	440 hrs/ha	81.4	105.8	195.0
Actual field capacity, ha/day	-	0.44	0.34	0.18
Field efficiency, %	-	64.1	71.5	67.1
Cost of operation, Rs/hr	-	58.50	51.42	44.73
Cost of weeding, Rs/ha	4400	1064	1210	1988
Saving in cost when compared to manual method, %	-	75.8	72.5	54.8
Saving in time when compared to manual method, %	-	95.8	94.6	89.8

observations recorded in **Table 2**.

The percentage of plant damage in the trail field during the operation of the weeders is shown in **Fig. 5**. The percentage of plant damaged was greater in Model A and followed by Model B. This is due to the fact that wheels and the blade caused damage to the plants while passing through rows. With sufficient head land and training in operation of the weeders in between row the percentage of plant damage can be minimized.

The results of the trail for weeding operation in pulse crop with the selected treatments are presented in **Table 3**.

The savings in cost and time of weeding operation using different models of the power weeder are shown in **Fig. 6** and **Fig. 7**.

It is clearly reflected from the figure that all the treatments the saving in cost and time was maximum in Model A (75.8 % and 95.5 %) followed by Model B (72.5 % and 94.8 %). The Model C recorded the lowest cost of saving and time is 57.8 % and 88.8 %.

Conclusions

Based on the analysis of the results the following conclusions are drawn:

- The working width of the power weeders were 60 cm, 45 cm and 30 cm respectively for Model A, B and C.
- Manual weeding using hand hoe registered maximum weeding efficiency of 83.10 % (wet basis) and 82.5 % (dry basis). The weeding efficiency of Model A was 74.10 % (wet basis) and 73.45 % (dry basis), Model B recorded 63.49 % (wet basis) and 64.15 % (dry basis) and Model C recorded lowest weeding efficiency of 43.43 % (wet basis) and 43.13 % (dry basis).
- The saving in cost of weeding operation with three models when compared to manual weeding were 75.8, 72.5 and 54.8 % respectively for Models A, B and C.
- The saving in time of weeding operation using with the three models when compared to the manual weeding was 95.8, 94.6 and 89.8 % respectively for Models A, B and C.

REFERENCES

Goel. A. K., D. Behera, B. K. Behera, S. K. Mohanty, and S. K. Nanda. 2008. Development and ergonomic evaluation of manually operated weeder for dryland crops. Agricultural Engineering International: the CIGR eJournal. Manuscript PM 08 009. Vol. X.

Padole, Y. B. 2007. Performance

Fig. 6 Saving in cost of weeding

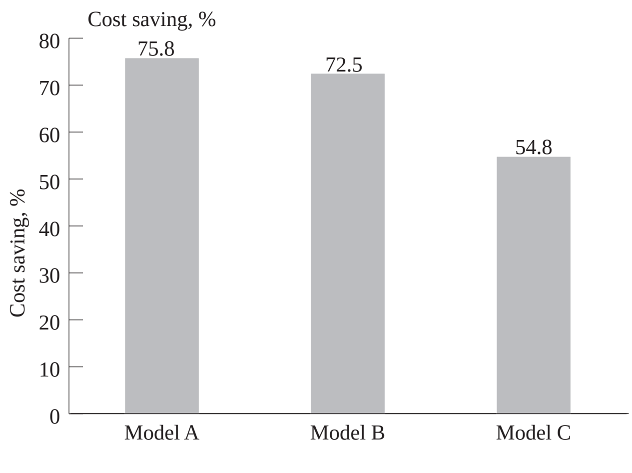
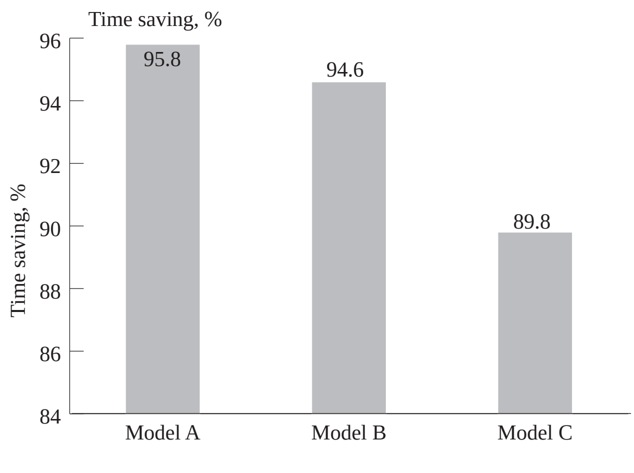


Fig. 7 Saving in time for weeding operation



evaluation of rotary power weeder. Agricultural Engineering Today. Vol. 31 (3 & 4): 30-33.
Pullen, D. W. M. and P. A. Cowell. 1997. An evaluation of the performance of mechanical weeding mechanisms for use in high speed inter-row weeding of arable crops. Journal of Agricultural Engineering Research, 67: 27-34.
Rajasekar, S. 2002. Design, development and performance of tractor drawn multirow rotary weeder. M.E (Ag.) thesis. Tamil Nadu Agricultural University, Coimbatore.
Rangasamy, K., M. Balasubramaniam, and K. R. Swaminathan. 1993. Evaluation of power weeder performance. Agric. Mech. in Asia, Africa and Latin America, 24(4): 16-22.

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EVENT CALENDAR

◆ **GFIA**

—The Global Forum for Innovations in Agriculture—
February 3–5, 2014, Abu Dhabi, UAE
http://www.innovationsinagriculture.com/about

◆ **FIMA**

—38 International Fair of Agricultural Machinery—
February 3–6, 2014, Zaragoza, SPAIN
http://www.fima-agricola.es

◆ **AETC**

—2014 Agricultural Equipment Technology Conference—
February 10–12, 2014, Kentucky, USA

◆ **48th Annual Convention**

Indian Society of Agricultural Engineers (ISAE)
February 21–23, 2014, Rajasthan, INDIA
http://www.isae.in

◆ **42nd International Symposium**

—Actual Tasks on Agricultural Engineering—
February 25-28, 2014, Opatija, CROATIA
http://atae.agr.hr/

◆ **IFPE2014 —Solutions come together—**

—The leading event and education resource for the fluid power, power transmission and motion control industries.
March 4-8, 2014, Braunschweig, GERMANY
http://www.ifpe.com

◆ **MCG2014**

—4th International Conference on Machine Control and Guidance—
March 18-20, 2014, Las Vegas, USA
http://www.mcg2014.de

◆ **RHEA-2014**

—Robotics and associated high-technologies and equipment for agriculture and forestry—
March 21-23, 2014, Madrid, SPAIN
http://www.rhea-conference.eu/2014/

◆ **ADAGENG 2014**

—12th International congress on mechanization & Energy in Agriculture—
June 3–6, 2014, Cappadocia, TURKIYE
http://www.adageng2014.com

◆ **DLG-Feldtage 2014**

—One of the largest agricultural machinery exhibition in Germany—
June 17-19, 2014, Hannover, GERMANY
http://www.dlg-feldtage.de/en.html

◆ **First International Field Days for crop production and agriculture machinery**

July 2–4, 2014, Volga Region, RUSSIAN
http://www.dlg.org/news_agriculture_pl.html?detail/dlg.org/1/2/6256

◆ **AgEng 2014 Zurich**

—Engineering for improving resource efficiency—
July 6–10, 2014, Zurich, SWITZERLAND
http://www.AgEng2014.ch

◆ **Canadian Society of Biosystems Engineers CSBE**

—Joint International Meeting with ASABE—
July 13-16, 2014, Montreal, CANADA
www.asabemeetings.org/

◆ **2014 International Symposium on Flexible Automation (ISFA 2014)**

July 14–16, 2014, Hyogo-ken, JAPAN
http://www-dsc.mech.eng.osaka-u.ac.jp/ISFA2014/

◆ **12th International Congress on Mechanization & Energy in Agriculture**

September 3-6, 2014, Cappadocia, TURKEY
http://www.adageng2014.com/

◆ **18th World Congress of CIGR**

—International Commission of Agricultural and Biosystems Engineering—
October 9-12, 2014, Beijing, CHINA
http://www.cigr2014.org

◆ **Agro Tech Russia 2014**

October 3-6, 2014, Moscow, RUSSIA
http://www.dlg-international.com/392.html

◆ **10th ECPA meeting**

—Conference theme: Precision agriculture for efficient resources management under changing global conditions—
July 12–16, 2015, ISRAEL

Determination of the Suitability Period of S-3 Diesel Oil when Used in Tractor Engines*

by
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Abstract

The diesel oil type S-3 specified for diesel engine has limited the suitability for diesel trucks for 8000 km, but didn't clarify its suitability if used in tractor engines.

It is known that the work style of farm tractor differs from that of other vehicles where tractors are used for all the activities in sever conditions and under the complete usage of the available power and capability, so there is no sign or indication of the usage period of this oil in tractor's engine.

The oil has been used on Cirta C6806 tractors. The manual book of the tractor's engine, Deutz recommends changing the oil every 100 hrs. Therefore the main goal of this research is to give the recommended working hours for S-3 diesel oil when used in farm tractor engines.

Five tractors have been used in this research and the engine oil was changed for the interval period of 20 hrs starting from 20, then 40, 60, 80, 100 and 120 hours. At the end of each period the oil of the five tractors was mixed and a sample was taken for testing. This procedure was repeated three times in order to obtain accurate results with statistical analysis.

The statistical analysis results showed that the S-3 diesel oil deteriorates after 40 working hours because of the great consumption of the oil after this period and therefore this research recommends that the usage period of S-3 oil should not exceed more than 40 working hours when it is used in tractor's engine.

Introduction

Crankcase oils are generally designed to provide adequate lubrication and as a coolant and sealant, keep the engine clean (free of dust and wear), minimize corrosion. To function properly, these oils must be formulated from mineral base oils of the appropriate viscosity, and additives are added to achieve the desired properties. However, during engine operation, oil ages; mainly by oxidation, decomposition and polymerization.

These processes result in the increased acidity of the oil, the depletion of additives and the formation of deposits, which thicken the oil. Nevertheless several factors influence the ageing of hydrocarbon based oils, and these include high engine temperature (which is characteristic of tropical conditions), the rate of air oil, and the type of additives used (8).

This applies especially:

1. If the engine is running too cold, in cold weather or through frequent spells of idling or intermittent running. This increases contamination from the fuel side.
2. If the engine is running hot, in hot weather or on heavy work. This accelerates deterioration of oil itself.
3. If the tractor is working in dusty fields, or if the air or oil filter is not working well. Increased quantities of abrasive matter will then be present in the oil.

It may sometimes pay to reduce the service life of the oil by as much as one-half.

In general, however, the recommended interval will apply, but do not be tempted to exceed it, even with the best oil. Complicated and costly laboratory analysis would be necessary to make sure that the oil is fit for further service that might otherwise have remained in the system. Allow enough time for complete drainage (9).

Materials and Methods

Five tractors have been used in this research; the oil has been used on Cirta C6806 tractors. The manual book of the tractor's engine, Deutz,

*A part of M.Sc.

recommends changing the oil every 100 hrs. Therefore the main goal of this research was to give the recommended working hours for the S-3 diesel oil when used in farm tractor engine.

The specifications of S-3 oil are

Code No.	153
SAE No.	30
Viscosity @40 ºC CST	87.76
Viscosity @100 ºC CST	10.29
Viscosity Index	98
Flash Point ºC (C.O.C)	228
Neut. No. (MgKOH/ gm Oil)	0.45
Carbon Res. % w/w	0.56
Sul. Ash % w/w	0.28

The engine oil was changed for interval period of 20 hrs starting from 20, then 40, 60, 80, 100, 120 hrs. At the end of each period the oil of the five tractors was mixed and a sample was taken for testing. This procedure was repeated three times in order to obtain accurate results with statistical analysis.

Seven parameters are used to determine the suitability of S-3 diesel oil when used in tractor's engines they are:

Viscosity

Viscosity is the most important property of lubricating oil. It is a measure of the resistance to flow; a thin oil, an oil of high fluidity, has a low viscosity; a thick oil, has a high viscosity. Viscosity increases with the oxidation of oil and contamination insoluble matter, and decreases with fuel dilution (5).

Viscosity Index (V.I.)

Viscosity index indicated the extent to which an oil changes in viscosity with changing temperature. The higher V.I., the less is the change. Paraffinic oils, which have high V.I. values, can influence oil consumption and reduce top-ring zone wear rates where high temperatures up to 200 ºC exist (7).

Flash Point

The flash point is the lowest temperature at which the oil flash when slight tilted its surface, therefore this point of the lubricating oil must be sufficiently high so that it may not flash during services (1).

Neutralization Number

This measures the ability of an oil to neutralize corrosive acids due to its reserve of alkalinity, which keeps the engine clean and prevents liner and ring wear. Furthermore, it provides a measure of oil's dispersant and oxidation resistant properties. The neutralize No. of used oil depends on operating conditions and the sulphur content of fuel used.

Carbone residue

The high temperature of the engine cylinder and piston breaks down the oil films, thus the burns and form the carbon. This carbon may pack at the piston rings and preventing them to function properly. Therefore the piston rings in the grooves obtaining poor compression, excessive oil consumption and scoring of cylinder walls. In this way formation of the carbon may cause poor performance and damage to the engine so a lubricant must be resistant to heat and forms a minimum amount of carbon during service (1).

For lubricating oils, viscosity is the most important single property. In a bearing operating properly, with fluid film separating the surfaces, the viscosity of the oil at the operating temperature is the property which determines the bearing friction, heat generation, and the rate of flow under given conditions of load, speed and bearing design.

The oil should be viscous enough to maintain a fluid film between the bearing surfaces in spite of pressure tending to squeeze it out while a reasonable factor of safety is essential, excessive viscosity mean unnecessary friction and heat generation. The rate of change of viscosity with temperature varies with different oils (4). The viscosity increases due to increase in combustion soot concentration. Oxidation of the lubricating oil, and the increase in organic acid, which helps to form lacquer and sludge, will also increase viscosity, the high viscosity is due to the large amount of insoluble material present as a result of inadequate cleaning by centrifuge, the flash point is affected by the same factors effecting viscosity (7). At high temperature acids are formed in the lubricating oil. These acids corrode the whole lubricating system and main parts of the engine (1). The sulphated ash increases, mainly because of the gradual increase in additives, e.g. calcium, resulting from oil replenishment and also due to leakage of combustion gases, laden with sulphur oxides from the fuel sulphur, to the sump (7). McGeehan (6) improved that piston top land design was due to quick seating of the top ring. That was more favorable pressure distribution among the ring. The combination of these factors increased the rings radial pressure at the start of the down stroke and thus decreased oil consumption. Research by Curtis (2) using instrumented pistons, however, did not confirm this postulation. He demonstrated, in fact, that the pressure rise in the top groove was actually lower with cut back top land than the with tight top land piston. Therefore high pressure rise on the top ring may not be the reason for better oil consumption with the cut back top land.

Low oil consumption with the cut back top land appears to be due to the fact that it minimizes the contact between the carbonaceous deposit pistons that cylinder liner carbon polishing wear was responsible for increased oil consumption. This wear was analyzed in relation to the pistons transverse motion, and it was concluded that the pistons tilting and carbon deposit build up on the top land were the cause of cylinder liner wear and high oil consumption.

The carbon deposits from particularly in the top groove and generally to lesser extent in the second groove of high output engines operating at high temperatures and these can lead to sluggish ring movement when the side clearance is taken up, to ring sticking and to possible leakage (5).

Result and Discussion

The sample which are taken from five tractors at each period starting from 20 working hours, then 40, 60, 80, 100 and 120 hours are mixed together to make one sample represents the mean of the period.

These means are tabulated in **Table 1**.

The results are statistically analysis by used C.R.D with unequal samples. The results are allocated in **Table 2**.

It is observed from the **Table 2** that the oil is deteriorated after 40 hours periods according to be mentioned by Banga, Curtis, Ishizuki, Jones, Lilly, McGeehan and Najjar.

Conclusion

The maximum usage period of S-3 diesel oil should not exceed more than 40 working hours if it is used in tractors engine.

The above suitability usage is considered too low.

REFERENCE

Banga, T. R. and N. Singh. 1979. Automobile Engineering, Khanna publishing, first edition, Delhi, India.

Curtis, J. M. 1981. Piston Ring Dynamics and its Influence on Power Cylinder Performance, SAE paper no. 810935.

Ishizuki, Y. and others. 1981. Effect of Cylinder Linear Wear on Oil Consumption in Heavy Duty Diesel Engine, SAE paper no. 810931.

Jones. F. R. 1963. Farm Gas Engine and Tractors, McGraw Hill book Co. Fourth edition, New York, U.S.A.

Lilly, L. C. R. 1984. Diesel Engine Reference Book, Butterwoth Co., Ltd, England.

McGeehan, J. 1979. A survey of the Mechanical Parameters Effecting Engine Oil Consumption, SAE paper no. 790864.

Najjar, Y. 1987. Lubricants and Fuels analysis as a guide for predictive Maintenance in Diesel Engine Fuel 66(3) March.

Ofunne, C. and Others. 1989. Studies on the Ageing Characteristics of Automotive Crankcase oils, Tribology International 22(6) December.

Shell Co. 1955. Know your Tractor, the Shell Petroleum Company Ltd. London, England.

Steel, R. G. D. and J. H. Torric. 1966. Principles and Procedures of Statistics, McGraw-Hill Book Co., Inc., U.S.A.

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Table 1 the mean of parameters according to different working hours

Parameters / Hours	20	40	60	80	100	120
Viscosity @40 ºC CST	100.64	98.11	99.80	98.64	97.70	95.55
Viscosity @100 ºC CST	11.13	11.03	11.34	11.36	11.31	11.14
Viscosity Index	95.33	99.66	102	101	102	102
Flash point ºC (C.O.C)	232.67	232.67	233	238	234	218
Neut. no. MgKOH/gm oil	1.01	1.38	1.48	1.58	1.25	1.18
Carbon Res. % w/w	0.83	0.87	0.94	0.94	0.88	0.66
Sulph. Ash % w/w	0.30	0.31	0.29	0.19	0.13	0.16
Oil Consumption Liter	0	0	1.44	0.97	0.12	0.08

Table 2 statistically analysis to the results

S.O.V	d.f	F Call.								F tab.	
		Vis.@ 40 ºC	Vis.@ 100 ºC	V.I	Flash Point ºC	Neut. No. MgKOH/gm	Carb. Res. % w/w	Sul. Ash % w/w	Oil Con. Lit.	5 %	1 %
Period	5	20.9**	0.77n.s	0.6n.s	5.64*	1.91n.s	3.09n.s	7.54*	2754.5**	4.38	8.74
Error	6										
Total	11										

Modification in Pantnagar Zero-Till Ferti-Seed Drill for Pulses

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Abstract

Pantnagar Zero-till Ferti-seed drill was modified for sowing Urd (Vigna Radiata) seed and found suitable for sowing at recommended seed rate of 25-30 kg/ha. The average visible mechanical grain damage was found as 2.44 %. Average seed dropped per metre length was quite closer to the required value at recommended seed spacing. The average germination counts in the field at 10 and 30 days after sowing (DAS) were found as 57 and 55 per square meter, respectively. The average plant to plant spacing and plant height were found to be 8.6 and 12.56 cm after 10 DAS while those were 9.9 and 39.10 cm after 30 DAS, respectively.

Introduction

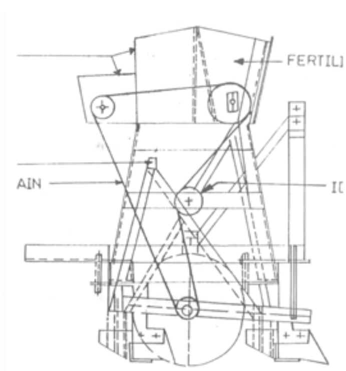
Pulses play an important role in Indian dietary and contain 20-30 % protein. The average availability of protein is about 50 g per capita in India, which is considerably less than the average requirement of protein (60 g) for an adult person. This is due to the fact that production of pulses is quite low in our country and thus it is not sufficient to meet the average protein requirement of a person. The persistent increase in the price of pulses is primarily due to almost stagnant production and continuous rise in demand to feed growing population. In order to bridge the gap between demand and supply of pulses, there is urgent need to increase the pulse production. The pulses especially, Urd (Vigna Radiata) and Moong (Vigna Mungo) are short duration crops and can be grown in the period available between wheat harvest and rice transplanting. The general practice is that the fields are left ploughed after harvest of wheat crop till transplanting of rice. If this period could be judiciously utilized for growing above pulses, then demand for pulses could be met to some extent.

The increase in food production has been merely due to use of agricultural inputs like high yielding varieties, fertilizers, irrigation, electricity as well as mechanization of farming practices. Since sowing is one of the most important farm operations, the time and method adopted for sowing decisively influences the germination and crop yield. It has been reported that there has been an increase in crop yield to the tune of 14-16 % through the use of seed-cum fertilizer drill and planter (Rastogi and Mittal, 1973). Buhtz *et al*. (1970) reported that higher emergence under zero-tillage was obtained on light to medium textured soil in short stubble with friable soil surface. Further they observed that numerous furrows created increased number of earthworms which helped in higher concentration of oxygen under zero-tillage. Roy and Vishwanathan (1977) conducted the study on seed drill and concluded that with the use of seed drill the yield can be increased to about 12.5 % and the time required for sowing reduced by 40 %. Proper inter row cropping can be accomplished with a seed-cum-fertilizer drill. Singh and Thakur (1979) developed a multi crop hand seed-drill having split type fluted roller metering device. They observed satisfactory seed distribution pattern in the laboratory and germination in field. Sharma *et al*. (1983) reported that for mechanized sowing of any crop a suitable sowing machine plays a vital role as it places the seed and fertilizer in the zone of moisture and at desired depth. Borin and Sartori (1995) conducted study on barley, soybean and maize using ridge tillage, no tillage and conventional tillage. They reported that many crop suffered greater or lesser yield reduction under conventional tillage to minimum tillage or no-tillage condition. The wheat crop adopted better (leading) to less reduction in yield (5-10 %) with minimum and no-tillage but other crops suffered about 20-25 % loss in yield. Singh and Singh (1995) developed a 9 row zero-till ferti-seed drill having inverted-T type furrow opener for timely sowing of wheat after the harvest of rice. They concluded that the crop sown by zero-till ferti-seed drill gave almost equal yield as compared to the conventional method of wheat sowing. The zero-till sowing technique was found to be more time and energy efficient. Wheat sowing was reported to be advance by 10-15 days with satisfactory performance in burnt rice residue field. Chaudhary (1998) conducted field experiment to investigate the effect of zero-till, strip till and conventional tillage sowing system. He concluded that zero-till sowing of wheat after rice harvesting was most time saving as compared to strip-till and conventional sowing method. In case of zero-till and strip-till sowing, the yield was obtained almost equal, however, it was higher as compared to conventional method of tilling and sowing.

The review of literature indicates that a sizeable amount of work has been done on zero-till and reduced tillage techniques and their comparison with conventional method for sowing. However, almost no work related to zero-till sowing of pulses has been reported so far. In view of the lack of suitable machinery for sowing pulses, present study was undertaken to explore the possibility of sowing pulses (Urd/Moong) directly after wheat harvest.

Fig. 1 View of Modified Pantnagar Zero-Till Ferti-Seed Drill

Fig. 2 Schematics of Modified Pantnagar Zero-Till Ferti-Seed Drill



Materials and Methods

The materials used and adopted methods for conducting experiment are described below under various heads.

Modification of Pantnagar Zero-till Ferti-seed Drill

The Pantnagar Zero-till Ferti-seed drill was modified by attaching a separate seed box and seed metering mechanism in the department of Farm Machinery and Power Engineering, College of Technology, G.B. Pant University of Agriculture and Technology, Pantnagar for sowing Urd/Moong (**Fig. 1** and **2**). The drill mainly consisted of the following components.

Frame

The frame of the drill was made up of mild steel angle iron (68.0 × 68.0 × 8 mm) of square cross-section. Numbers of holes were provided on the frame of the drill at a regular interval of 25.4 mm for adjusting the spacing between furrow openers. In order to sow Urd & Moong seed five furrow openers were utilized and were set at a spacing of 300 mm.

Seeding Attachment

The seeding attachment consisted of seed box and seed metering mechanism as depicted in **Figs. 1** and **2**.

Seed box:

The seed box of the seeding mechanism was made up of mild steel sheet. The box was fabricated taking into consideration the capacity required, bulk density and angle of repose of Urd and Moong seeds. The overall length of box was kept about 1480 mm having total height and average width of about 205 and 187.50 mm, respectively with total capacity of about 35 kg. The seed box was provided with two mild steel clamps, each of size 190.0 × 35.0 mm, having two holes of 7.0 mm diameter. This seed box along with seed metering mechanism was attached to the frame of the existing Pantnagar zero-till-Ferti-seed drill with the help of 4 bolts of sizes 7.0 mm diameter and 42.0 mm length.

Seed metering mechanism

A separate fluted roller type seed metering device was designed and developed with 8 numbers of grooves (**Fig. 3**) for sowing the Urd seed. The detail design procedure of the roller is presented below.

a) Design for number of grooves

The numbers of groves on the fluted roller were determined with the help of following expression:

$$l_f = (8 \times S \times r \times d_g) / (10 \times \rho \times d_f^2 \times N_f \times i)$$

Where,

l_f = Exposed length of fluted roller, cm

S = Seed rate, kg/ha

ρ = Bulk density of seed, g/cm^3

r = Row spacing, m

d_f = Diameter of flute, cm

N_f = Number of flutes

d_g = Diameter of ground wheel, m

i = Transmission ratio = Nf /Ng

N_f = Number revolution of fluted roller, rpm

N_g = Number of revolution of ground wheel, rpm.

For designing purpose, the recommended seed rate of 30 kg/ha with a row to row spacing of 300 mm was considered for Urd crop. The diameter of the ground wheel was taken as 380 mm same as of existing one. The width of the flute, bulk density of Urd seed and transmission ratio were taken as 13.0 mm, 0.862 g/cc and 1 : 2, respectively. Assuming the exposure length of fluted roller as 5 mm and substituting the values in above equation the number of grooves comes out to be 8.

b) Diameter of fluted roller

The diameter of the fluted roller was determined by the following expression:

$D_r = [N_f (d_f + S_f)] / \pi$

Where,

D_r = Diameter of fluted roller, mm

d_f = Diameter of flute, mm

S_f = Spacing between flutes, mm

Calculated value of D_r = 47.9 mm.

The other dimensions of the fluted roller were kept as per the BIS standard. The length of fluted roller was kept as 39.8 mm where as the radii were kept 34.7 and 47.90 mm. The depth of groove and diameter of groove were kept as 6.6 and 13.00 mm, respectively. A hole of 16.2 mm was provided through out the fluted roller to fit it on to the roller shaft.

Feed cut-off roller

A feed cutoff roller was provided in order to check the excess seed flowing out of the seed feed cup. The length and diameter of the feed cut off roller were kept as 38.9 mm and 42.0 mm, respectively. A central hole of 16.2 mm diameter was made to pass the roller shaft through it.

Power Transmission System

The power to the seed and fertilizer metering device was transmitted through a lugged ground wheel having 380 mm diameter. On the shaft of this wheel a mild steel sprocket having 18 numbers of teeth was fixed. Another sprocket was fitted to the fluted roller shaft having 36 teeth. This provided a speed ratio of 2:1 between the ground wheel and fluted roller shaft. A roller chain with 13.0 mm pitch and 1196 mm length was used to transfer the power from ground wheel to the fluted roller shaft. An idler sprocket was provided to adjust the chain tension to ensure proper power transmission. The same arrangement of power transmission was used to power the seed metering mechanism of the seeding attachment provided separately on the drill for Urd sowing.

Experimental Technique

Laboratory test

Calibration of seed drill

The modified seed drill was calibrated for Urd sowing in laboratory by placing the seed drill on a leveled ground and jacked up to facilitate the rotation of ground wheel freely. Laboratory test was carried for 40 revolution of ground wheel for different exposure length to determine seed rate for Urd crop. Seeds dropped from each seed tube were collected separately in the polythene bags and weighed and there after seed rate was determined. Same procedure was repeated by changing the exposure length of fluted roller till the required seed rate was obtained and seed rate as determined by the equation given as under:

$W = [q \times 10^6 (100 \pm S)] / \pi Dnd$

Where,

W = Seed rate, kg/ha

q = Quality of seed dropped per revolution of ground wheel, g

n = Number of furrow openers

d = Distance between to successive furrow openers, cm

S = Slip, %

D = Diameter of ground wheel, cm

Visible mechanical grain damage

In order to determine visible mechanical grain damage a known quantity of sample was taken from the calibrated sample received from each furrow opener. The damaged grains were separated manually from the sample and weighed. Thereafter, percentage visible mechanical grain damage was calculated using the following **Eqn**.:

Visible mechanical grain damage, % = [Weight of damaged seed in the sample (g) / Total weight of the sample (g)] × 100

Uniformity in seed distribution

To determine uniformity in seed distribution, seed drill was moved to a marked distance on a leveled surface. Thereafter, the seeds dropped in marked distance were collected and weighed.

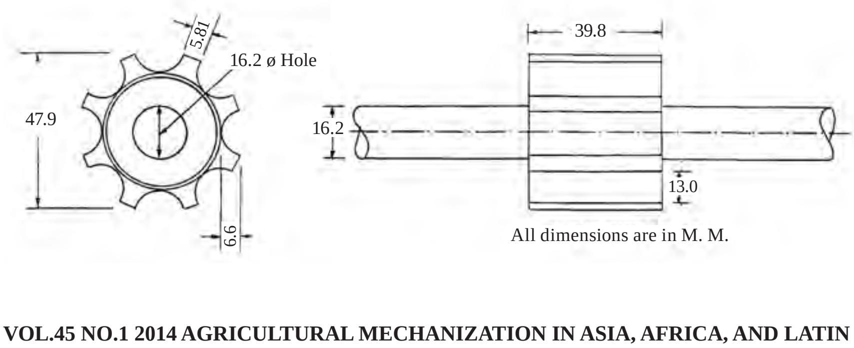
Seed distribution pattern

The test was performed to observe the seed distribution pattern, i.e. the manner in which seed placement in furrow would take place. The seed drill having seed was moved to a predetermined distance with uniform speed on a leveled surface. Three papers equal to the determined distance of test run having grease (semi-solid lubricant) on its surface were spread just below the seed tubes. The seed dropped from tube deposited on the paper surface.

Germination test

In order to determine the germination percentage, hundred Urd seeds were put on blotting paper and covered with tracing paper, rolled to prevent transfer of moisture and heat. Thereafter, the roll was moist with water and kept in incubator. Rolled seed was moistened at least one time in one day for one week. After one week samples were taken out from the incubator and the numbers of germinated seeds were counted. Germination percentage was calculated using following **Eqn**.

Fig. 3 Schematic of Seed Metering Roller for Metering Pulses (Urd/Moong)



Germination percentage = [(No. of germinated seed) / (Total number of seed taken for sample)] × 100

Performance Evaluation in the Field

Details about Experiment Field

The performance of the modified drill was evaluated in manually harvested wheat field of 0.34 ha area. The metering mechanism was adjusted to give recommended seed rate of 30 kg/ha without fertilizer application. Prior to sowing Urd crop, data pertaining to previous crop, initial cone index of the soil surface was determined with the help of cone penetrometer and soil samples were collected to determine the moisture content and bulk density. After taking initial observation of field, modified drill was used for sowing Urd seed and average depth of sowing, effective time in sowing, speed of operation and wheel slippage were determined.

Measurement of Soil Parameters

Determination of moisture content and bulk density

To determine soil moisture content, samples were collected randomly from experimental field and were kept in polythene bags. The wet weight of the sample was determined with the use of an electronic balance. Thereafter, the samples were kept in oven at 105 ± 1 ºC for 24 h. After 24 h of drying, samples were taken out, cooled and weighed for determining its dry weight. The moisture content was determined by the following **Eqn.**:

Moisture content, % = [(Wet weight, g − Dry weight, g) / Dry wet, g] × 100

In order to determine bulk density of soil, core sampler was sunk randomly in field by hammering it up to full height and then dug out along with soil. The projected portion of soil from top and bottom were removed and total weight of core sampler along with soil was determined. after that core sampler alongwith soil was kept in oven at 105 ± 1 ºC for 24 h. After drying at specified temperature with time, samples were taken out, cooled and weighed for its dry weight. The bulk density of soil was determined by the following **Eqn.**:

Bulk density, g/cc = (Dry weight of soil, g) / (Volume of core sampler, $cm^{3)}$

Volume of core sampler = $\pi/4\, D^2\, L$

Where,

D = Diameter of core sampler, cm

L = Height of core sampler, cm

Determination of cone index

A standard cone penetrometer (Model BL 250 Ec, Baker Marcer type (C-10, CL = 0.002 mm) having 26.18 mm cone base diameter and cone angle as 30 degree was used for determining of cone index. The penetrometer was gently inserted into the soil at uniform load. For every one inch (25.4 mm) depth dial gauge reading was recorded. After that penetrometer was calibrated for applied load and gauge deflection and a relation was established between these parameters. The cone index was determined from the following **Eqn.**:

$CI = 0.025Y + 0.099$

Where,

CI = Cone index, kg/cm^2

Y = Gauge deflection, subdivisions

Determination of Machine Parameters

Determination of time requirement for Urd sowing

Total time taken between the commence and end of sowing operation, turning and breakdown losses throughout the operation were recorded for determination of sowing time for Urd. The effective time required in sowing was determined by subtracting the various time losses from the total time.

Determination of slip

In order to determine wheel slip, the drive wheel of the tractor was marked to facilitate the counting of wheel revolutions. A corresponding position on the ground was also marked when tractor was moving forward with implement at load. The distance travelled by the tractor wheel while working in the soil at load and without load was measured and wheel slip was calculated as under:

Wheel slip, % = [(Distance travelled at no load − Distance travelled at load) / Distance travelled at no load] × 100

Determination of fuel requirement

Amount of fuel required for sowing was determined by filling the fuel tank upto its brim at the time of beginning of sowing operation. After covering whole test area the fuel tank was again refilled to the previous level. The fuel required to refill the tank to its previous level gave the actual fuel consumed.

Determination of forward speed and field efficiency

The forward speed of operation was determined by measuring the distance travelled by drive wheel of the tractor and time required to travel the same distance.

The field efficiency (ratio of actual area covered to the theoretical area covered per hour) was determined by following **Eqn.**:

Field efficiency, % = [(Actual area coverd / Theoretical area)] × 100

Measurement of Crop Parameters

Germination count, plant spacing and plant height

Germination count, plant spacing and plant height were recorded in field at 10 days and 30 days after sowing (DAS). For this purpose a square iron frame of 1 × 1 m size was placed randomly at different locations in the field. After placing square iron frame, the number of plants enclosed in frame was counted and were considered as germination count. The successive plant spacing and plant height from ground level to the top of plant were measured.

Results and Discussion

The performance of modified

Pantnagar zero-till ferti-seed drill was evaluated in field for sowing Urd crop in manually harvested wheat field without performing any tillage operation in an area of 0.34 ha. Before conducting actual experiment, modified drill was calibrated in the laboratory. The results of the laboratory as well as field experiments are presented below;

Modification in Pantnagar Zero-Till Ferti-Seed Drill

The Pantnagar zero-till ferti-seed drill was modified by attaching a seeding attachment which included a seed box and five sets of seed metering device. The overall length of the seed box was 1,480 mm with a capacity of 35 kg seed. The fluted rollers were fabricated using the designed dimensions of flutes and their requisite numbers. Other dimensions were kept as per the BIS -6813, 1973 for fluted roller. The performance of the seeding mechanism in respect of delivery of seed, visible mechanical grain damage was found satisfactory.

Laboratory Test

Calibration of Seeding Attachment

The seeding attachment of modified drill delivered almost equal amount of seed at 5 mm exposure length of fluted roller for desired seed rate. The maximum and minimum seed rate obtained were 30.6 and 30.4 kg/ha, respectively with an average seed rate of 30.54 kg/ha and standard deviation as 0.41. The reason for variation in seed rate among the furrow opener might be due to change in exposure length, which is again due to faulty fitting of the rollers on the transmission roller shaft. However, the designed fluted roller with 8 numbers of grooves and 5 mm exposure length was able to deliver the recommended seed rate of 30 kg/ha.

Visible Mechanical Grain Damage

The average visible mechanical damage of Urd seed from all the furrow openers were obtained as 2.45, 2.43 and 2.44 % with overall visible damage as 2.44 % (**Table 1**) which was very close to the acceptable range with standard deviation as 0.49.

Uniformity in Seed Distribution

It can be seen from the results of uniformity in seed distribution presented in Table 1 that all seed metering devices dropped almost equal quantity of seed with overall standard deviation as 0.07 and coefficient of variation as 6.81 %. The seed dropped from each furrow opener varied from 1.04 to 1.05 g with an average of 1.04 g. The variation in seed dropped from each furrow opener might be due to manufacturing defect of fluted roller. However, there was no remarkable variation in respect of uniformity in seed distribution from all furrow

Table 1 Averaged values of various parameters of harvested field, seed, soil, machine and crop

Sl. No.	Parameters		Values
1.0	**Parameters of harvested field**		
1.1	Number of plants/m^2		297.00
1.1	Number of tillers/hill		6.57
1.3	Height of stubble, cm		22.37
1.4	Area of the field, ha		0.34
2.0	**Seed parameters**		
2.1	Dimension, mm	Length	4.75
		Diameter	3.60
2.2	Bulk density, g/cc		0.862
2.3	Angle of repose, degree		25.50-32.95
2.4	Germination, %		82.00
2.5	Test weight, g		47.30
2.6	Moisture content, % (db)		11.50
3.0	**Soil Parameters**		
3.1	Moisture content, % (db)		15.56
3.2	Bulk density, g/cc		1.63
3.3.	Cone index, kg/cm^2		0.60-2.10
4.0	**Machine parameters**		
4.1	Area covered ha/h		0.917
4.2	Seed rate, kg/ha		30.54
4.3	Visible mechanical grain damage		2.44
4.4	Uniformity in seed distribution		1.04
4.5	Uniformity in seed distribution pattern		6.25-6.67
4.6	Time requirement, min		30.92
4.7	Fuel requirement, l/h		3.67
4.8	Forward Speed, km/h		6.12
4.9	Wheel slip, %		5.96
4.10	Turning losses in the field, min		18.90
4.11	Breakdown losses, min		4.18
4.12	Total time taken (including all losses), min.		54.00
4.13	Theoretical field capacity, ha/h		1.02
4.14	Actual field capacity, ha/h		0.65
4.15	Field efficiency, %		71.11
5.0	**Crop parameters**		
5.1	Germination count/m^2	10 DAS	57.00
		30 DAS	55.00
5.2	Plant spacing, cm	10 DAS	8.60
		30 DAS	9.90
5.3	Plant height, cm	10 DAS	12.60
		30 DAS	39.10

openers. The average weight of seed dropped per meter length was quite close to the desired value of 0.9 g.

Seed Distribution Pattern

The overall seed to seed spacing was found as 6.08 cm, which is closer to the required value of 7-10 cm with overall standard deviation as 0.43 and coefficient of variation as 0.07.

Germination Test

On an average the germination percentage, test weight and moisture content of Urd seeds were observed to be 82 %, 47.3 g and 11.50 % on wet basis, respectively (**Table 1**).

Soil Physical Parameters

Soil Moisture Content and Bulk Density

The data (**Table 1**) revealed that soil moisture in the field varied from 10.48 to 20.0 % on dry weight basis. The moisture content was less toward the point of higher elevation, whereas the higher moisture content was found where the slope was maximum. However, the average moisture content was found to be about 15.5 % at the time of sowing. Also where the residue concentration was more, the soil moisture content was higher as compared to the place where there was less residue of previous crop providing mulching effect. As no-tillage operation was performed prior to the sowing therefore more soil moisture was observed in the field. The bulk density of soil determined at the time of sowing as 1.58 to 1.69 g/cc with an average bulk density of 1.63 g/cc. The higher bulk density may be due to consolidation of the soil particles as no-tillage practices were adopted after the harvest of wheat crop.

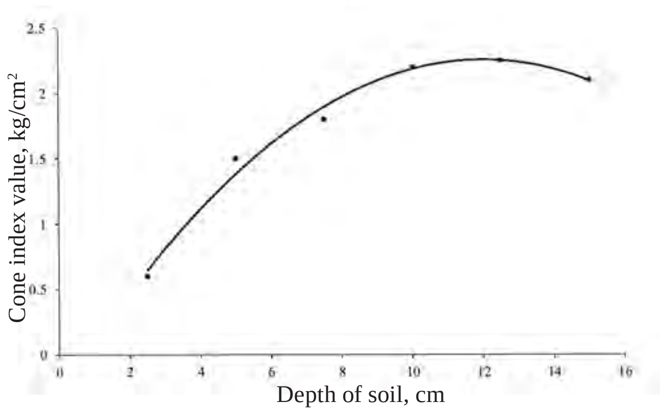
Soil Cone Index

The relationship between depth and cone index values has been shown in **Fig. 4**. The data (**Table 1**) revealed that on an average the soil strength at the top was less as compared to higher depths of 15 cm. In general, the cone index value increased with the increase in depth but at higher depth of 15 cm it declined. The average cone index values were found as 0.6, 1.50, 1.80, 2.20, 2.25 and 2.10 kg/cm^2 for the depths of 2.5, 5.0, 7.5, 10.0, 12.5 and 15.0 cm, respectively. The increase in cone index value with increase in depth may be due to compactness of soil. The decrease in cone index value at 15 cm depth might be due to the presence of soft layer of soil just below the hard pan.

Machine Parameters

The total area covered under test with modified drill was 0.917 ha/h. In general, the total time requirement for sowing Urd seed by modified drill was found as 1.50 h/ha with a total fuel requirement of about 5.50 l/ha (**Table 1**). The speed of operation was found to be 6.12 km/h with wheel slip as 5.96 %. The field capacity was obtained as 0.65 ha/h with a field efficiency of about 71.11 %.

Fig. 4 Relationship between Cone Index and Depth of Soil



Crop Parameters

Germination Count, Plant Spacing and Plant Height

The data presented in **Table 1** reveals that germination count varied from minimum of 46 to maximum of 73 with average germination count as 57 plants per square meter after 10 DAS and the same were found ranging from 45 to 66 with an average of 55 plants per square meter after 30 DAS. Further, it can be seen from **Table 1** that some of the plants could not survive and the percentage of mortality was determined to be 3.50. The plant spacing varied from 6.10 to 14.35 cm with an average of 8.60 cm at 10 DAS, whereas the same was determined as 7.91 to 14.21 cm with an average of 9.9 cm after 30 DAS. The increase in plant spacing after 30 DAS may be due to mortality of few plants after germination. However, no much difference between the plant spacing at 10 and 30 DAS was observed and was within the recommended range of 7-10 cm. The average plant height was found as 12.56 cm at 10 DAS, where as it was 39.10 cm at 30 DAS.

Conclusions

The modified Pantnagar Zero-Till Ferti-Seed drill for sowing Urd crop was evaluated in actual field condition and the performance was found satisfactory. The fluted roller of seed metering device for sowing urd crop was also found suitable for recommended seed rate. From the laboratory as well as field trials, following conclusions could be drawn:

1. The recommended seed rate of 30 kg/ha could be achieved at 5 mm exposure length of fluted roller having 8 numbers of grooves with 6.6 mm depth.
2. The average visible mechanical grain damage was found as 2.44

% and uniformity in seed distribution in laboratory varied from 1.04 to 1.05 g with overall standard deviation of 0.07 and coefficient of variation as 6.81%. Average seed dropped in 1.0 m length was quite close to the required value of 0.9 g. The overall seed to seed spacing in laboratory was found as 6.08 cm, which is closer to the recommended seed to seed spacing of 7-10 cm.

3. The average germination count in the field after 10 and 30 DAS was found as 57 and 55 per square meter, respectively. The average plant to plant spacing in the field was found as 8.6 and 9.9 cm, respectively while average plant height was found as 12.56 and 39.10 cm, respectively for 10 and 30 DAS.

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REFERENCES

Borin, M. and L. Sartori. 1995. Barley, soybean and maize production using ridge tillage, No- tillage and conventional tillage in North East Italy. J. Agric. Engg. Res. 62: 229-236.

Buhtz, E., O. Bosses, R. Herzog, and U. Waldschmidt. 1970. Albrecht-Taer Arch. 14: 795-812 (Cf. Adv. Agron 25, 77-123).

Choudhary, V. P. 1998. Investigation on zero, strip and conventional till techniques on wheat crop establishment after rice. Thesis, M. Tech. G. B. Pant University of Agriculture and Technology, Pantnagar, U. P.

Rastogi, R. A. and J. P. Mittal. 1973. Roll of improved implements in modern agriculture. I.S.A.E. Paper, 6:(5).

Roy, K. and K. N. Vishwanathan. 1977. Increased agriculture productivity through technology - A review Proc. National Seminar on Technology for Agricultural Development, Chandigarh. pp 85-88.

Sharma, D. N., N. K. Bansal, and M. L. Jain. 1983. Design, development and testing of bullock-drawn single row seed-cum fertilizers. AMA. 14(2): 37-38.

Singh, B. and T. P. Singh. 1995. Development and performance evaluation of zero-till ferti seed-drill. J. Agric. Engg. 32(1-4): 13-23.

Singh, Bachchan, and T. C. Thakur. 1979. Sugarbeat hand drill for small and marginal farmers in developing countries. AMA. 10(1): 59-63.

Verma, U. N. and V. C. Shrivastava. 1989. Weed management in wheat under Zero and optimum tillage conditions. Indian J. Agron. 34 (2): 176-179.

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NEWS

EIMA Agrimach: International Exhibition and conference on Agri-Machinery Equipment

The exposition of agricultural machinery sponsored by FICCI, the Federation of Indian Chambers of Commerce and Industry, and FederUnacoma, the Italian Agricultural Machine Manufacturer Federation, took place in New Delhi, India from December 5th to 7th 2013. Nearly 270 exhibitors participated, compared to 245 in 2011, from India, Italy, South Korea, China, Japan, the Czech Republic, Switzerland, Spain and Turkey. The visitors came from all the Indian states as well as from other countries in Asia, such as Indonesia, Iraq, Nepal and Thailand. The exposition offered a complete panorama of mechanization for all types of farming operations. Also, it provided the ideal occasion for monitoring world markets and dealing with salient technical and agricultural policy issues with a large number of conferences and meetings.

The Indian Market is one of the biggest and most consistent in the world. Last year, sales of tractors rated at greater than 30 hp climbed to 600,000 units to make the Indian market the world leader. Moreover, the production capacity of agriculture has grown steadily. Currently, the farming workforce accounts for more than 52 % of the population making their living in rural territories out of a total population of 1.2 billion. However, the weight of agriculture in the formation of India's GDP has lost ground in recent years to the industrial and services sectors, declining from 50 % in the 1950s to 13.7 % in the fiscal year of 2012-2013. Need for guaranteeing food security, providing the population with a greater variety of products and improving the standard of living in rural communities requires a more widespread deployment of agricultural machinery and equipment to enable higher yields per hectare and more high quality products. Thus the growth of mechanization and increasing power input are two of the priority objectives of Indian agricultural policy. Agrievolution, during the exposition, drew up a brighter future for the Indian market, and this outlook calls for growth over the coming five years of 5 % to 8 % annually. ■■

Fuel Properties of Denatured Anhydrous and Aqueous Ethanol of Different Proofs

by

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Abstract

This study investigates the fuel properties viz. relative density, kinematics viscosity, flash point, fire point and gross heat of combustion of denatured anhydrous ethanol (200º) and denatured aqueous ethanol of different proofs (190º, 180º and 170º) as a fuel for small spark ignition petrol start kerosene run type engines used in agriculture work and compared with kerosene fuel properties. The observed results of study indicated that the denatured ethanols of 200º, 190º, 180º and 170º proof were found to have similar power producing capabilities as kerosene.

Introduction

Countries around the world are grappling with the problem of meeting the ever-increasing demand for petro based fuel within the constraints of international commitment, legal requirement, environmental concerns and limited resources. Increasing energy need are therefore, being supplemented with various alternate sources such as solar, biomass, wind, nuclear etc. However, concentrated efforts are being focused on the alternate liquid or gaseous fuels particularly derived from renewable sources to supplement petro fuels in internal combustion engines.

Oil is the second largest source of energy in India, accounting for over 31 % of the country's overall energy consumption. India, like many other developing countries, is a net importer of energy. More than 25 % of India's primary energy needs are being met through imports mainly in the form of crude oil and natural gas. The oil import bill reached a 19 month high of US $ 8.1 billion in the month of April 2010. The rising oil import bill has been a serious concern for the Indian economy (http://www.cpcl.co.in/coporate_information-chair-addre.htm). The Government of India has therefore have dedicated to explore use of renewable fuels like ethanol and biodiesel for internal combustion engines. In this context ethanol has been identified for blending with petrol and shall save huge amount of foreign exchange. At the same time it is expected to improve farmer's condition because ethanol is primarily derived in India from sugar cane.

Ethanol in a high octane fuel and its use reduces emission of CO, particulate matter, cancer causing benzene and butadiene to a very high level. Ethanol blends dramatically reduce emission of HC, which is major contributor to the depletion of the ozone layer; reduces net carbon dioxide emission upto 100 percent (Lakshmanan, 2005).

A mixture of 10 percent anhydrous alcohol with 90 percent gasoline (Gasohol) is used as a commercial fuel in over 35 countries including USA, Canada and France (Anon, 1996). The government of India has now initiated blending of 5 percent ethanol with petrol for use as engine fuel to converse petrol. The government also envisages extending this limit to 10 percent level near future. (Tewari, 2003)

The use of ethanol as engine fuel poses the problem of absorption of moisture from atmosphere. It absorbs moisture until it has the composition of 95 : 5 of alcohol and water respectively. The commercially available ethanol grades contain 10-20 percent water and therefore, they are aqueous in nature and have the

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potential for lower emission CO, HC and NO_x (Chandan Kumar, 2002).

In agriculture sector and for domestic use small petrol start kerosene run engines are being promoted. Because manufacturing and burning of ethanol do not increase green house effect and for achieving Bhart III and IV emission standards it is obligatory to use ethanol by taking advantage of low emission property in spark ignition engines. Due to higher octane number, a hike in compression ratio increases power output of engine without knocking so this will do great deal to improve engine performance and economy. However, it is essential to study the effect using aqueous ethanol on engine needs to establish its feasibility.

In light of the above facts, a research work was undertaken on the utilization of denatured anhydrous and aqueous ethanol in place of kerosene for constant speed spark ignition petrol start kerosene run type engines with the objective: To determine the characteristics fuel properties of denatured anhydrous and aqueous ethanol of different proofs.

Materials and Methods

The experiments were conducted in the Bio Energy Technology Laboratory of the Department of Farm Machinery and Power Engineering, College of Technology, G.B. Pant University of Agriculture and Technology, Pantnagar. The experiments were carried out using kerosene and different ethanol proofs denatured with kerosene as fuel.

Ethanol (CH_3CH_2OH) is a colourless liquid, which is chemically known as ethyl alcohol. Its concentration is expressed as ethanol proof. A proof number represents twice the ethanol concentration. A 200º proof ethanol is anhydrous ethanol. The anhydrous ethanol (200º proof) of JEBSEN & JESSEN GmbH & Co. Germany was procured from the local market. Ethanol proofs of 170º, 180º and 190º were prepared from the anhydrous ethanol by adding different amount of distilled water to it. The details of different levels of ethanol proofs selected for the study are given in **Table 1**.

The details of aqueous denatured ethanol prepared from anhydrous ethanol are given in **Table 2**.

Initially 200 ml samples were prepared for each proof of ethanol using different proportions of ethanol and distilled water added on volume basis. The denaturing of different proofs of ethanol was done by adding 10 percent kerosene on volume basis to each proof. The purpose of denaturing the different proof of ethanol was to make it unfit for human consumption. The fuel properties such as relative density, kinematics viscosity, flash point, fire point and gross heat of combustion of denatured anhydrous and aqueous ethanol of different proofs and kerosene were determined as per IS 1448 [P: XXXII]: 1992; IS 1448 [P: XXV]: 1976; IS 1448 [P: XXI]: 1992 and IS 1448 [P: VI]: 1984 respectively.

Results and Discussion

Various fuel properties of denatured anhydrous and aqueous ethanol and kerosene fuels were determined.

Relative density

The relative density of kerosene and different proofs of ethanol with and without denaturing with kerosene is shown in **Table 3**. The table shows that the relative density of kerosene was observed as 0.8028. The relative density of kerosene as reported by Gruse (1960) is in the range of 0.77 to 0.82 and that by Sahay (1992) is 0.827. The relative density of ethanol having 200º, 190º, 180º and 170º proof without denaturing with kerosene was observed as 0.7981, 0.8103, 0.8235 and 0.8450 respectively. Workman *et al.* (1983) reported the relative density of 200º, 180º and 160º proof ethanol as 0.78, 0.81 and 0.83 respectively. Thus, the observed relative density of kerosene and ethanol of different proofs without denaturing with kerosene was found to be similar to those reported in earlier studies.

The **Table** also indicates that the relative density of 200º, 190º, 180º and 170º proof ethanol denatured with 10 percent kerosene was 0.7912, 0.8105, 0.8254 and 0.8306 respectively. The denatured aqueous ethanol of 190º, 180º and 170º proof used as engine fuels had their relative density 0.96, 2.82 and 3.46 percent higher than that of kerosene. However, the relative density of denatured 200º proof ethanol was 1.44 percent less than that of kerosene. The observed relative density was

Table 1 Different Aqueous Ethanol Proofs Selected

Proof of Ethanol	Water Content, % by volume	Ethanol, % by volume
200º	0	100
190º	5	95
180º	10	90
170º	15	85

Table 2 Denatured Anhydrous and Aqueous Ethanol Prepared for the Test

Proof of Ethanol	Fuel Constituents, %		
	Ethanol	Distilled Water	Kerosene
200º	90.0	0.0	10
190º	85.5	4.5	10
180º	81.0	9.0	10
170º	76.5	13.5	10

found to be 1.58, 2.39, 1.67, 1.42, 2.08, 0.56, 1.16, 1.68 and 0.44 percent higher than the values reported by Chandan Kumar (2002) for kerosene and 200º, 190º, 180º and 170º proof ethanol as well as denatured ethanol of 200º, 190º, 180º and 170º proof respectively.

Kinematic Viscosity

Kinematic viscosity of kerosene and different ethanol proofs with and without denaturing with kerosene is shown in **Table 3**. The kinematic viscosity of kerosene was found to be 1.898 cS at 38 ºC. The kinematic viscosity of kerosene at 380 C may range between 1.4 to 2.2 cS as reported by Sharma and Mohan (1984). The kinematic viscosity of 200º, 190º, 180º and 170º ethanol proofs without denaturing with kerosene was found to be 1.989, 2.512, 2.63 and 2.971 respectively. The higher kinematic viscosity observed for the lower proof of ethanol was due to presence of water in them. The kinematic viscosity at 38 ºC of 200º, 190º, 180º and 170º proof ethanol denatured with 10 percent kerosene was observed as 1.65, 1.779, 1.92 and 2.1 cS respectively. The kinematic viscosity of denatured ethanol proofs was found to be lower than that of ethanol proofs which were not denatured with kerosene. This is due to the fact that the kinematic viscosity of kerosene was less than that of lower proof ethanol and 10 percent kerosene by volume was used for denaturing of ethanol proofs. The observed kinematic viscosity was found 3.1, 1.0, 0.8, 0.6, 0.4 and 0.6 percent lower than the values reported by Chandan Kumar (2002) for kerosene, 200º, 190º, 180º and 170º proof ethanol and 190º proof denatured ethanol respectively. The kinematic viscosity was observed 0.2, 0.2 and 0.6 percent higher for 200º, 180º and 170º proof denatured ethanol when compared with the values reported by Chandan Kumar (2002) respectively. The kinematic viscosity of denatured ethanol proofs was found to be lower than that of ethanol proofs which were not denatured with kerosene. This is due to the fact that the kinematic viscosity of kerosene was less than that of lower proofs of ethanol and 10 percent kerosene by volume was used for denaturing of ethanol proofs.

Gross Heat of Combustion

The gross heat of combustion of kerosene and ethanol proofs is shown in **Table 3**. The table indicates that the gross heat of combustion of kerosene was 46690.2 kJ/kg (11169.9 kCal/kg). Gruse (1960) reported that the gross heat of combustion of kerosene may range between 43890 to 47040 kJ/kg. The gross heat of combustion of 200º, 190º, 180º and 170º proof ethanol without denaturing was 31696.9, 27220.2, 26718.6 and 22567.8 kJ/kg respectively. Workman *et al*. (1983) reported the gross heat of combustion of 200º, 180º and 160º proof ethanol as 31531, 28625 and 25718 kJ/kg respectively. Thus, the observed gross heat of combustion of different fuel types was found to be similar to that reported by other researchers. The gross heat of combustion of 200º, 190º, 180º and 170º proof denatured ethanol was found as 32934.2, 31588.3, 29692.6 and 26961.0 kJ/kg respectively. The observed values reveal that ethanol of 200º, 190º, 180º and 170º proof when denatured with 10 percent kerosene had their gross heat of combustion 29.5, 32.3, 36.4 and 42.3 percent lower than that of kerosene. The gross heat of combustion of 200º, 190º, 180º and 170º proof ethanol without denaturing was found to be 32.1, 41.7, 42.8 and 51.7 percent lower than that of kerosene. Further, the comparison of different ethanol proofs indicate that denatured ethanol of 200º, 190º, 180º and 170º proof had 3.9, 16.0, 11.1 and 19.5 percent higher gross heat of combustion than the similar proofs without denatured with kerosene. The difference in gross heat of combustion was found to be vary 0.5, −5.3, 4.6, 0.5, 11.6, −0.6, −0.2, 4.1 and 10.7 percent compared to the one reported by Chandan Kumar (2002) for kerosene, 200º, 190º, 180º and 170º proof ethanol and denatured ethanol of 200º, 190º, 180º and 170º proof respectively. Since, the selected denatured ethanol proofs have their gross heat of combustion less than that of kerosene, it is expected that the requirement of these fuels to produce power similar to kerosene would be higher.

Table 3 Different fuel properties of Different Fuels at 15 ºC

Fuel Type	Relative density at 15 ºC	Kinematic viscosity at 38 ºC, cS	Gross heat of combustion, kCal/kg	Flash point, ºC	Fire point, ºC
Kerosene	0.8028	1.898	11169.9	46.2	52.7
Different Proof of Ethanol					
200º Proof	0.7981	1.989	7583.0	12.4	18.7
190º Proof	0.8103	2.512	6512.0	13.4	19.4
180º Proof	0.8235	2.630	6392.0	15.0	23.3
170º Proof	0.8450	2.971	5399.0	16.1	25.4
Ethanol Denatured with 10 % Kerosene					
200º Proof	0.7912	1.650	7879.0	13.7	20.2
190º Proof	0.8105	1.779	7557.0	15.0	20.8
180º Proof	0.8254	1.920	7103.5	16.0	24.6
170º Proof	0.8306	2.100	6450.0	17.1	27.1

Density of distilled water at 15 ºC = 0.9991 g/cc

Flash and Fire Point

The flash and fire point of kerosene and other selected fuels are shown in **Table 3**. The flash and fire point of kerosene was found to be

46.2 ºC and 52.7 ºC respectively. Bhaskararao (1984) reported the flash point of kerosene greater than 42 ºC and fire point greater than ºC The flash point of 200º, 190º, 180º and 170º proof ethanol without denaturing with kerosene was found to be 12.4, 13.4, 15.0 and 16.1 ºC respectively. The fire point of above proofs of ethanol was found to be 18.7, 19.4, 23.3 and 25.4 ºC respectively. The flash point of denatured ethanol having 200º, 190º, 180ºand 170º proof was found as 13.7, 15.0, 16.0 and 17.1 ºC and the fire point as 20.2, 20.8, 24.6 and 27.1 ºC respectively. The flash point of anhydrous (2000 proof) ethanol as reported by Cheremisinoff (1979) is 13.9 ºC. The flash point of anhydrous (2000 proof) ethanol has also been reported as 13 ºC (http://www.wikipedia.org.com). The observed flash point has difference of 0.1, −0.2, 0.1, 0.2, 0.1, 0.1, 0.2, 0.2 and 0.1 ºC with respect to the observations of Chandan Kumar (2002) for kerosene, 200º, 190º, 180º and 170º proof ethanol and 200º, 190º, 180º and 170º proof denatured ethanol respectively. The difference in fire point are 0.1, −0.2, −0.1, 0.2, 0.1, 0.1, 0.2, 0.2 and 0.1 ºC for kerosene, 200º, 190º, 180º and 170º proof ethanol and 200º, 190º, 180º and 170º proof denatured ethanol respectively.

The flash and fire point of ethanol proofs denatured with kerosene or without denaturing were observed to be much lower than that of kerosene.

Conclusions

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

The 190º, 180º and 170º proof ethanol prepared by adding 5, 10 and 15 percent water to anhydrous ethanol (200º proof) by volume did not show any sign of phase separation. The miscibility of water with anhydrous ethanol was satisfactory.

The denaturing of 200º, 190º, 180º and 170º proof ethanol with 10 percent kerosene by volume was adequate to add odour of kerosene to ethanol proofs and make them unfit for human consumption.

The relative density of ethanol of different proofs with and without denaturing increases with decrease in proof of ethanol. The relative density at 15 ºC of kerosene was found to be 0.8028 and that of 200º, 190º, 180º and 170º proof ethanol without denaturing was 0.7981, 0.8103, 0.8235 and 0.8450 respectively. The denatured ethanol of 200º, 190º, 180º and 170º proof had their relative density as 0.7912, 0.8105, 0.8254 and 0.8306 respectively.

The kinematic viscosity of the ethanol of different proofs with and without denaturing increases with decrease in the proof of ethanol. The kinematic viscosity at 38 ºC of kerosene was observed to be 1.898 cS and that of 200º, 190º, 180º and 170º ethanol proofs without denaturing was 1.989, 2.512, 2.630 and 2.971 cS respectively. The denatured ethanol of 200º, 190º, 180º and 170º proof had their kinematic viscosity as 1.650, 1.779, 1.920 and 2.100 cS respectively.

The gross heat of combustion of ethanol of different proofs was affected by water content in the proof as well as denaturing with kerosene.

1. The gross heat of combustion of kerosene was found to be 46690.2 kJ/kg (11169.9 kCal/kg).
2. The gross heat of combustion of 200º, 190º, 180º and 170º proof ethanol without denaturing with kerosene found as 31696.9, 27220.2, 26718.6 and 22567.8 kJ/kg respectively. The observed values are 29.5 to 42.3 percent lower than that of kerosene.
3. The gross heat of combustion of denatured 200º, 190º, 180º and 170º proof ethanol was found as 32934.2, 31588.3, 29692.6 and 26961.0 kJ/kg respectively which are 32.1 to 51.7 percent lower than that of kerosene.

The flash and fire point of ethanol of different proofs was found to increase with increase in water content in proofs as well as their denaturing with kerosene.

1. The flash point of kerosene was observed to be 46.2 ºC and its fire point as 52.7 ºC.
2. The flash point of ethanol of 200º, 190º, 180º and 170º proofs without denaturing and with denaturing was found to be 12.4, 13.4, 15.0, 16.1, 13.7, 15.0, 16.0 and 17.1 ºC respectively.
3. The fire point of ethanol of 200º, 190º, 180º and 170º proofs without denaturing and with denaturing was found to be 18.7, 19.4, 23.3, 25.4, 20.2, 20.8, 24.6 and 27.10 C respectively.

On the basis of above findings, it can be said that ethanol of 200º, 190º, 180º and 170º proof may be used to replace kerosene as fuel in the petrol start kerosene run small spark engine. The selected ethanol proofs are stable and they have similar power producing capabilities as kerosene. However, the experiments (testing of denatured anhydrous and aqueous ethanol fuel on engines) need to be conducted for confirmation of fuel suitability for small spark ignition petrol start kerosene run engines used in India.

REFERENCES

Chandan Kumar. 2002. Studies on utilization of denatured anhydrous and aqueous ethanol in a constant speed SI Engine, M. Tech. Thesis, Department of Farm Machinery and Power Engineering, G.B. Pant University of Agriculture and Technology, Pantnagar, India.

Cheremisinoff, N. P. 1979. Gasohol for Energy Production. Ann. Ar-

bor Science Pub. Inc. USA. 55 p.
Gruse, W. A. and D. R. Stevens. 1960. Chemical Technology of Petroleum. McGraw Hill, Inc. USA.
http://www.cpcl.co.in/coporate_information-chair-addre.htm
http://www.wikipedia.org.com
India. 2006. Energy: Crude Oil and Petroleum Products. Pp. 291.
IS: 1448(P: VI) 1984. Methods of test for petroleum and its products. Heat of combustion of liquid hydrocarbon fuels by bomb calorimeter method.
IS: 1448(P: XXI) 1992. Methods of test for petroleum and its products. Determination of flash point and fire point.
IS: 1448(P: XXV) 1976. Methods of test for petroleum and its products. Determination of kinematic and dynamic viscosity.
IS: 1448(P: XXXII) 1992. Petroleum and its products-methods of test density and relative density.
Sahay, J. 1992. Elements of Agricultural Engineering. Standard Publication Distributors, 3rd ed. Delhi. 54 p.
Sharma, S. P. and C. Mohan. 1984. Fuels and combustion.
Workman, J. P., G. L. Miller, and J. L. Smith. 1983. Alcohol-diesel combustion characteristics. Transactions of the ASAE. 26(03): 642-645.

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Effects of Different Tillage and Press Wheel Weight on Soil Cone Index and Dryland Wheat Yield in Khuzestan Iran

by
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Abstract

Combined effects of tillage and press wheel weight with the impact upon soil compaction were shown to have an important role on seedling emergence, crop establishment, and plant growth. Using the proper combination of tillage implements and determining suitable weight of press wheels have been recommended for greater growth and grain yield. This research was conducted to investigate the effects of different tillage and press wheel weights on wheat seedling emergence and yield under dryland conditions in Izeh, Khuzestan province, Iran. Also, Soil cone index and yield components were recorded. Tillage treatments including conventional tillage (Moldboard plow and disk), reduced tillage (double disks, chisel and disk) and no tillage were applied. Seeding treatments including grain drills using different press wheels and weights (4, 5 and 8 kg/cm wheel-width) were used. The experiment was conducted as a split factorial using complete randomized block design with three replications. Results were indicated that reduced tillage system, increased seedling emergence, and grain yield. Independent press wheel drill with reduced cone index and increased emergence rate (54 %) was significantly ($p < 0.01$) the greatest treatment in wheat yield production compared to other treatments. Also the highest grain yield, (2202.9 kg/ha) was produced where 5 kg/cm width of press wheel was applied. In order to increase seedling emergence rate and grain yield under dryland conditions, using an independent 5 kg/cm press wheel width followed by reduced tillage was recommended where the experiment was conducted.

Introduction

Tillage can provide appropriate seed bed for plant by changing soil structure and decreasing cone index, which has direct effect on seedling and rate of emergence (Aiken, *et al*., 1997; McMaster, *et al*., 2000 and 2002; Lapen, *et al*., 2004). Suitable selection of tillage methods to improve seed bed for plant emergence, growing, and higher grain yield was explained for different soil conditions (Barzegar, *et al*., 2004; Licht and Al-Kaisi, 2005). Reduced tillage provides better soil physical conditions for seedling emergence, root growth by decreasing cone index, compared to conventional tillage (Helm, 2005). Proper use of tillage could provide enough soil moisture at seeding, hence enhance its ability for germination, and the early establishment of roots. Press wheels as parts of seeding machines can create the condition for uniform plant growth and increased yield (Karayel, *et al*., 2004). Planter's performance can be related to many factors such as seed vitality, and soil temperature at the time of germination (McMaster, *et al*., 2002). Furthermore, the presence of soil moisture, pores around seed (Eskandari, 1997; Eskandari and Mahmoodi, 2000), and sowing depth (Ozmerzi *et al*., 2002) would also affect crop yield. In addition to that Press wheels by creating appropriate conditions on top of the seeds, leave a good effect on germination and seedling emergence rate as well (Asoodar, *et al*., 2006; Vamerali, *et al*., 2006). In fact, Press wheels allow faster seed germination and increased emergence rate (Rainbow and Dare, 1997; Naser and selles, 1995; Asoodar, *et al*., 2006) by reducing sowing depth (Karayel, *et al.*, 2004) thus improve performance via emergence and faster establishment (Radford, 1996). Moreover, using the right combination of planter tools for instance, furrow openers and press wheels make the qualified effect on furrow preparation and moisture absorption (Tessier, *et al.*, 2003). Also press wheel weights should be corrected at the time of seeding operation (Asoodar, *et al.*, 2006). Unfortunately press wheels in most drills have been implemented on one or two axels in groups and the independent regulation of the wheel's weight is not proportionate to the possible condition, so it is necessary to study the press wheel weights variations and their effects on dryland wheat yield. Also seed bed formation by tillage systems on dryland soil conditions in this region will be determined.

Table 1 analysis of variance for cone index in different depths (kPa)

Source of variation	df	0-5 cm depth		5-10 cm depth		10-20 cm depth	
		F	Ms	F	Ms	F	Ms
Replicate	2	0.12	146.3	1.33	1495.3	15.47	5659.1
Tillage (T)	3	3.84n.s	4742.1	9.45*	10627	28.01**	10247.9
Ea	6	3.11	1233.6	1.81	1124.5	0.48	365.8
Planter (P)	1	5.22*	2027.2	7.52**	4664.5	1.96n.s	1498.5
Weight (W)	2	4.4*	1745.1	1.17n.s	727.5	1.95n.s	1490.6
T × P	3	3.79*	1506	3.28*	2036.2	0.73n.s	558.3
T × W	6	0.3n.s	117.7	0.85n.s	528.7	0.93n.s	711.4
P × W	2	0.37n.s	147.4	1.69n.s	1046.8	0.34n.s	258.3
T × P × W	6	0.7n.s	279.1	1.69n.s	1050.9	0.98n.s	744.9
Eb	40	-	396.9	-	620.4	-	762.8
CV		20.32		18.38		17.34	

*and **shown significant at p <.05 and p <.01 respectively and n.s shown not difference in each column

Material and Methods

The experiment was carried out in Khuzestan province which is located in 31º 51´ N and 49º 52´ E. The annual rainfall within average of a 10-year period in this area has been 757.52 mm. Naturally, January and February received the greatest amount of rainfall. Four tillage methods (T) consisting of no-tillage, reduced tillage a (disk and chisel), reduced tillage b (twice disked) and conventional tillage (moldboard plow followed by a disk). Tillage depth of plow, disk and chisel was 15, 10-15 and 25 cm respectively. Sowing practices were performed using drill planters (P) equipped with two axles, press wheels, and independent press wheels. The two axle press wheel drills included rubber and metal press wheels. Wheel weight (W) was 4, 5 and 8 kg/cm of press wheel width. The experiment was conducted using a factorial split complete randomized block design with three replications.

To determine soil cone index in the depth of 30 cm a penetrologer was used. This machine was equipped with an 80 cm axle to the end of which there was a small cone with 30° vertex angle and 2 cm^2 base area. This sampling was performed at the emergence and blooming times (Nidal and Hamdeh, 2003). The number of emerged seedlings of two lines at one meter length in each plot was counted daily to calculate seedling emergence percentage (Hemat, 1995), using **Eqn. 1**.

$$M = [ppsm / (spsm \times P \times G)] \times 100 \quad (1)$$

Where: M is the percent of seedling emergence, ppsm is the number of emerged bushes in m^2, spsm is the number of sowing seed in m^2, P is pure seed percentage and G is the vitality (germination percentage) of seed.

Furthermore, **Eqn. 2**: was used to determine the emergence rate index (Chen, *et al.*, 2004; Tessier, *et al.*, 1991).

$$SE = [\Sigma (Ni / di)] / L \quad (2)$$

Where: SE is the rate of emergence (daily in one meter), Ni is the number of seeds emerged every day, and finally L is the length of line (m).

This practice continued for so long as the number of emerged seeds was not increased.

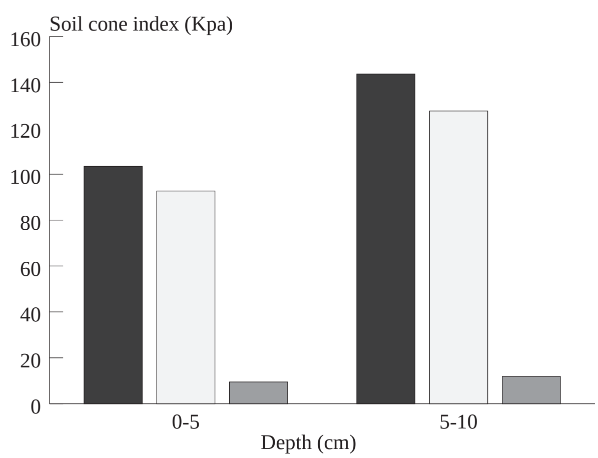
At harvesting time, 3 m^2 in each plot was harvested. Then grain yield, biomass, spike number, number of thousand grains, and the harvest index were calculated.

Results and Discussion

Soil Cone Index

Tillage and sowing machines showed significant effect on soil cone index; **Table 1**. Independent and two axle press wheel drills including rubber and metal press

Fig. 1 The effect of sowing machine on soil cone index



wheels have shown their own different effects on soil compaction.

There was significant difference in cone index between the two drills at 0-5 and 5-10 cm depths. Furthermore, two-axle press wheel drill caused greater resistance (103.4 kPa) in 0-5 cm depth (**Fig. 1**). Moreover, the 11.57 % greater difference was due to press wheel profile. In fact, the independent press wheel drill was made of rubber whereas the press wheels in two-axle drill was made of metal and showed no flexibility at soil unevenness and caused more pressure on soil.

There was a significant difference in soil cone index, at 0-5 cm depth for 8 kg/cm and the weights of 4 and 5 kg/cm press wheel width **Table 2**. The 8 kg/cm press wheel weight showed 18 % and 23 % greater on cone index where compared to 4 and 5 kg/cm press wheel weight respectively.

The interaction effect of tillage and sowing machine on soil cone index for no tillage and two axle press wheel drill was the highest (138.92 kPa) compared to conventional tillage as shown in **Fig. 2**.

Seedling and Rate of Emergence

Tillage and sowing machine showed significant ($p \leq 0.05$) effect on emergence rate **Table 3**. Tillage, sowing machine, and press wheel weights all affected the emergence rate at the level of probability of $p < .01$. Moreover, the interaction effect of sowing machines was significant where seedling emergence was compared.

The interaction effect of sowing machine and press wheel weights on seedling emergence was significant where press wheel with 5 kg/cm weight was applied. Indeed, the independent press wheel drill using 5 kg/cm weight with lower cone index would lead to improve emergence rate as shown in **Fig. 3**.

No-tillage seeding showed the lowest emergence rate (1.78) and was different from other treatments

Table 2 Mean of soil cone index using different press wheel weights

Depth	Weight	8 kg/cm	5 kg/cm	4 kg/cm
0-5, cm		107.44[a]	90.81[b]	85.68[b]
5-10, cm		139.76[a]	137.63[a]	129.34[a]

Table 3 Analysis of mean variance for seedling and rate of emergence

Source of variation	df	Emergence rate		Seedling emergence	
		F	Ms	F	Ms
Repeat	2	1.1	0.337	1.31	23.55
Tillage (T)	3	6.67*	2.043	24.03**	432.14
Ea	6	1.18	0.306	0.39	17.98
Planter (P)	1	63.18**	16.45	104.69**	4798.73
Weight (W)	2	7.69**	2.003	28.6**	1310.77
T × P	3	1.56[n.s]	0.41	0.31[n.s]	14.14
T × W	6	1.9[n.s]	0.495	0.47[n.s]	21.48
P × W	2	6.22**	1.62	7.14**	327.16
T × P × W	6	2.31*	0.6003	0.49[n.s]	22.32
Eb	40	-	0.26	-	45.83
CV		22.52		10.21	

* and ** shown significant at the level of 5 and 1 percentage and n.s shown no difference

Table 4 Mean of seedling and rate of emergence using different tillage systems

Tillage	Rate of emergence	Seedling emergence
Conventional tillage (moldboard plow & disk)	2.45[a]	66.61[a]
Reduced tillage (twice disk)	2.40[a]	71.36[a]
Reduced tillage (chisel disk)	2.43[a]	67.56[a]
No-tillage	1.76[b]	59.61[b]

Common letter shown not significant in each row

Fig. 2 Interaction effect of tillage and sowing machine on soil cone index

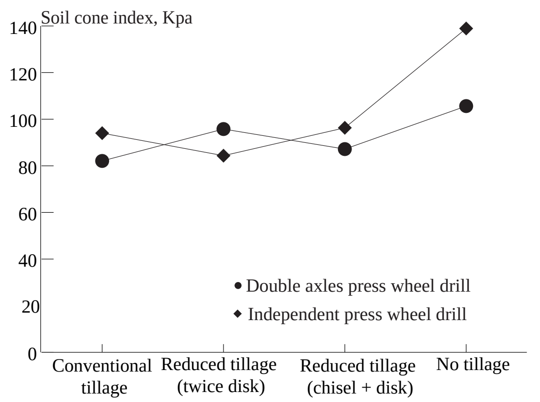
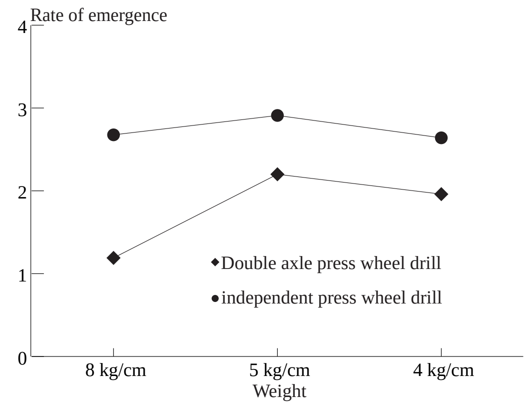


Fig. 3 Interaction effect of machine and press wheel weights on rate of emergence



(**Table 4**). Higher soil cone index in no-till treatment lead to reduce emergence rate. Finlay *et al.* (2003) also reported that tillage of any form could increase the emergence rate by decreasing soil cone index. However, reduced and conventional tillage did not show any significant difference where seedling emergence was compared.

Double disk reduced tillage (a) showed 71.36 % seedling emergence which was 4 % and 12 % higher than reduced tillage (chisel and disk, b) and no-tillage respectively.

Two-axle press wheel drill was different from the independent press wheel drill regarding emergence percentage and rate (**Table 5**). Independent press wheel drill with a difference of 54 % in the emergence rate and 28 % in seedling emergence showed a better result compared to two axle drill.

What is more, 8, 4 and 5 kg/cm of press wheel width affected the rate and percentage of plant emergence significantly (**Table 6**). Rainbow and Dare (1997); Chen *et al.* (2004) and Asoodar *et al.* (2006), also obtained the same results. This effect was mostly due to the increased contact surface between seed and soil, the increased ability of moisture absorption by seed, and the maintenance of soil cone index on seed in a specified area. Also the reduced rate and percentage of emergence for 8 kg/cm press wheel treatment was the result of an increased soil cone index to a depth of 5 cm, compared to other press wheel weights, **Table 6**.

Wheat Yield and Components

Machine and press wheel weight showed a great impact on grain yield and spike numbers (**Table 7**). Effects of combined planters and press wheels were shown to be grateful at seeding operation for

Table 5 press wheel effect on seedling emergence and rate

	Independent press wheel drill	Two axle press wheel drill	Different
Rate of emergence	2.74[a]	1.78[b]	53.93 %
Seedling emergence	74.45[a]	58.12[b]	28.09 %

Common letter shown not significant in each row

Table 6 Seedling and rate of emergence using different press wheel weights

Press wheels weight (kg/cm of press wheel width)	8 kg/cm	5 kg/cm	4 kg/cm
Rate of emergence	1.93[b]	2.44[a]	2.42[a]
Seedling of emergence	57.79[b]	71.25[a]	69.81[a]

Common letter shown not significant in each row

Table 7 Analysis of variance for grain yield, spikes number in m^2, press wheel weights and 1000 seeds

Source of variation	df	Grain yield					
		yield		spikes number in m^2		1000 grain seed weight	
		F	Ms	F	Ms	F	Ms
Replication	2	3.07	1537197.8	1.17	4322.24	0.84	15.33
Tillage	3	0.71n.s	3527757	10.33n.s	4898.5	1.18n.s	21.48
E[a]	6	4.17	499931	3	3683.48	1.89n.s	18.15
Planter	1	92.87[**]	11138704	54.71[**]	67203.27	52.03[**]	498.75
Weight	2	1.36[*]	42753.2	2.09[*]	109.6	1.45[n.s]	13.89
T × P	3	2.25[n.s]	269899	0.99[n.s]	1215.18	0.51[n.s]	4.86
T × W	6	0.59[n.s]	71064	0.36[n.s]	447.95	0.44[n.s]	4.24
P × W	2	0.17[n.s]	20137	0.2[n.s]	250.99	0.03[n.s]	0.253
T × P × W	6	1.29[n.s]	155293	1.22[n.s]	1503.81	1.54[n.s]	14.75
E[b]	40	-	119935	-	1226.4	-	9.58
CV			19.13		17.43		8.73

[*]and [**]shown significant different at the level of 5 and 1 percent and n.s shown no difference

Fig. 4 Effect of different grain drills on wheat grain yield

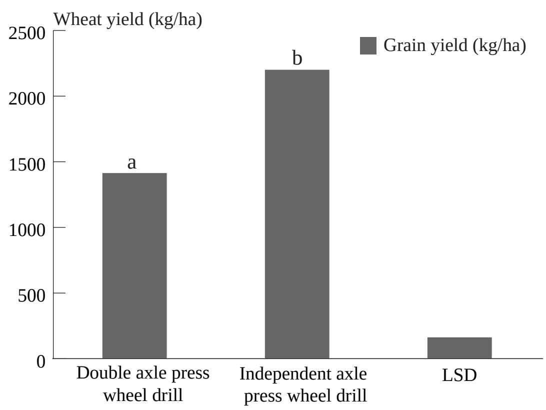
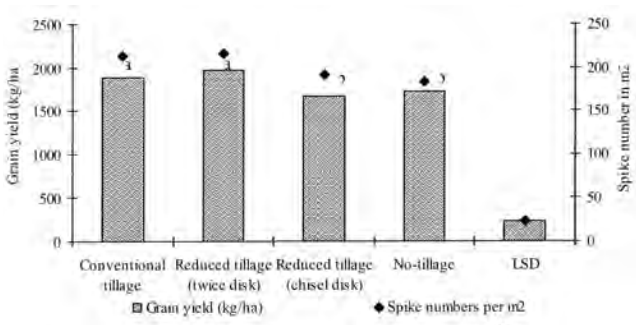


Fig. 5 Effect of tillage system on spike numbers per m^2 and grain yield



grain production.

Independent press wheel drill produced higher grain yield (2202.9 kg/ha) which was about 55.5 % greater, compared to two axle press wheel drill (**Fig. 4**). Decreased soil cone index, increased seedling emergence, and enhanced spike number per m^2 all lead to increase yield where independent press wheel drill was used.

Decreased cone index and also improved emergence rate (**Table 4**) in reduced tillage treatment (double disks, a), could increase the spike numbers per m^2 and lead to increase yield. Likewise, Ciha (1982), Kreuz (1990) and Finlay *et al.* (2003) found similar results. .

There was no significant difference between 1000 wheat-grain weight and tillage operation, but no till was shown significantly the lowest (**Table 8**). No tillage treatment lowered the absorption of soil moisture which was actually due to its higher soil compaction than other tillage systems, and for this reason, this treatment had been suffering lack of moisture and was reduced the weight of 1000 wheat- grain.

Independent press wheel drills was shown higher 1000 grain weight (38.08 g) compared to two axle press wheel drill (**Fig. 6**).

Conclusions

Reduced tillage treatment with adjustable press wheel drill showed significant effects on soil cone index and also seedling emergence rate. Reduced tillage treatment (double disks, a) showed significant impact on soil cone index ($p \leq 0.05$) and the amount of grain yield (1967.7 kg/ha) which was the greatest produced yield among other treatments. Independent press wheel drill with 5 kg/cm weight of press wheel width was also the greatest where 2202.9 kg/ha grain was harvested. To summarize, basically the results of this study suggest that, reduced tillage treatment (double disks, a) can be applicable in the area and similar regions where dryland wheat grain is cultivated.

REFERENCES

Aiken, R. M., G. N. Flerchinger, H. J. Farahani, and K. E. Johnson. 1997. Energy balance simulation for surface soil and residue temperatures with incomplete cover. Agron. J. 89. 405-416.

Asoodar, M. A., A. M. Bakhshandeh, H. Afraseabi, and A. Shafeinia. 2006. Effects of press wheel weight and soil moisture at sowing on grain yield. Journal of Agronomy, 5(20) pp: 278-283.

Barzegar, A. R., M. A. Asoodar, A. R. Eftekhar, and S. J. Herbert. 2004. Tillage effects on soil physical properties and performance of irrigated wheat and clover in semi arid region. Agron. J. 3(4): 237-242.

Barzegar, A. R., A. M. Hashemi, S. J. Herbert, and M. A. Asoodar. 2004. Interactive effects of tillage system and soil water content on aggregate size distribution for seedbed preparation in Fluvisols in southwest Iran. Soil and tillage Res. 78. 45-52.

Barzegar, A. R., M. H. Mosavi, M. A. Asoodar, and S. J. Herbert. 2004. Root mass distribution of winter wheat as influenced by different tillage systems in semi arid region. Agron. J. 3(3): 223-228.

Chen, Y., S. Tessier, and B. Irvin. 2004. Drill and crop performances as affected by different drill configuration for no-till seeding. Soil and tillage. Res. 77. 147-155.

Ciha, A. G. 1982. Yield and components of four spring wheat cultivar selection. Agron. J. 78. 795-799.

Eskandari, A. 1997. Correct selection of drill for sowing dryland wheat. Water, soil, machine journal. Number of 42, Pp 27-33.

Eskandari, A. and H. Mahmoodi. 2000. Affect of fertilizer on grain yield dryland wheat. Seedling and seed journal. No. 17. Number of 2. Pp 8-10.

Finlay, M. J., J. M. Tisdall, and B. M. McKenzie. 2003. Affect of tillage blow the seed on emergence of wheat seedlings in a hard setting soil. Soil and tillage Res. 28(3): 213-225.

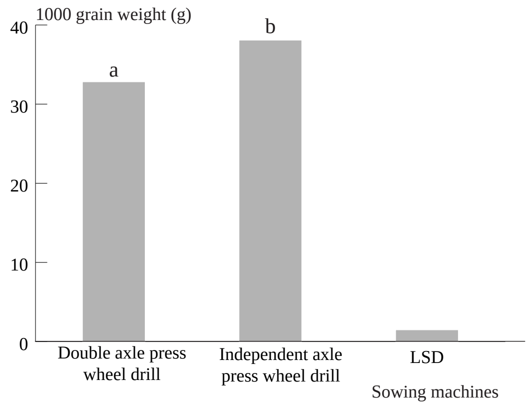
Helm, V. 2005. Conservation tillage: corn, grain sorghum, and wheat in Dallas County, Texas. Soil and

Table 8 Mean of 1000 seeds using different tillage

Tillage	Weight of grain 1000 seeds
Conventional tillage (moldboard plow and disk)	36.77[a]
Reduced tillage (twice disk)	35.72[ab]
Reduced tillage (chisel and disk)	35.13[ab]
No-tillage	34.16[b]

Common letter shown not significant in each row

Fig. 6 Effect of sowing machines on 1000 grain weight



Tillage Res. 23(5): 356-366.
Hemat, A. 1995. Effects of seed bed property and sowing method on seedling emergence watery wheat. Agricultural science Iran. No. 27. Number of 4. Pp. 55-68.
Karayel, D., Z. B. Barut, and A. Ozmerzi. 2004. Mathematical modeling of vacuum pressure on a precision seeder. Biosystems. Eng. 87(4): 437-444.
Kreuz, E. 1990. The influence of no-plough tillage for winter wheat in a three-course rotation on yield and structure. Archive-Fur-Acker. 34(9): 635-641.
Lapen, D. R., G. C. Topp, M. E. Edwards, E. G. Gregorich, and W. E. Curnoe. 2004. Combination cone penetration resistance/ water content instrumentation to evaluated cone penetration- water content relationships in tillage research. Soil and Tillage Res. 79: 51-62.
Licht, M. A. and M. Al-kaisi, 2005. Strip- tillage effect on seedbed soil temperature and other soil physical properties. Soil and Tillage Res. 80: 233-249.
McMaster, G. S., D. B. Palic, and G. H. Dunn, 2002. Soil management alters seedling emergence and subsequent autumn growth and yield in dryland winter wheat-fallow systems in the central Great Plains on a clay loam soil. Soil and Tillage Res. 65: 193-206.
McMaster, G. S., R. M. Aiken, and D. C. Nielsen. 2000. Optimizing wheat harvest cutting height for harvest efficiency and soil and water conservation. Agron. J. 92: 1104-1108.
Naser, H. M. and F. Selles. 1995. Seedling emergence as influenced by aggregate size, bulk density, and penetration resistance of the seedbed. Soil and Tillage Res. 34: 61-76.
Nidal, H. and A. Hamdeh. 2003. Soil compaction and root distribution for okra as affected by tillage and vehicle parameters. Soil and Tillage Res. 74: 25-35.
Radford, B. J. 1996. Effect of pres wheel and depth of semi dwarf and tall wheat's. Oust. J. of exp. Agric. 26(6): 697-702.
Rainbow, R. W. and M. W. Dare. 1997. Summary of nitrogen and phosphorus fertilizer placement research 1993-1995 in farming systems developments in Adelaide. Cooperative research center for soil and land management. 128-129.
Tessier, S., K. E. Saxton, and R. I. Papendick. 2003. Furrow opener and press wheel effects on seed environment and wheat emergence. Soil and Tillage Res. 39 (7): 547-559.
Tessier, S., K. E. Saxton, R. I. Papendick, and G. M. Hyde. 1991. Zero-tillage furrow opener effects on seed environment and wheat emergence. Soil and Tillage Res. 21: 347- 360.
Vamerali, T., M. Bertocco, and L. Sartori. 2006. Effects of new wide-sweep opener for no-till planter on seed zone properties and root establishment in maize: A comparison with double-disk opener. Soil and Tillage Res. 89: 196-209.

■■

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His paper on 'Performance of a Pulse Width Modulated (PWM) Single to Multifold Outlet System for Variable-rate Anhydrous Ammonia Application' in Transaction of the American Society of Agricultural and Biological Engineering (ASABE), received ASABE's Superior Paper award in 2012. He is also member of editorial board of 5 journals, grant reviewer including World Bank, serves Professional societies like ASABE in leadership position, and received several research grants. ■■

Development and Evaluation of Seed Metering System for Water Soaked Cotton Seeds

by

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Abstact

A metering system was developed for a precision cotton planter. The developed metering system plants two water soaked hybrid cotton seeds per hill. The exact size of the groove was selected based on the physical properties of the soaked cotton seeds. The metering mechanism of the precision cotton planter was evaluated in the laboratory for the seed distribution pattern at three angles of seed metering plate with horizontal (40º, 45º and 50º) and three forward speeds (2.0, 3.0 & 4.0 km/h). The 45º angle of inclination of seed metering plate with horizontal and forward speed of 3.0 km/h resulted into highest percentage of two seeds/drop (56.03 %), low percentage of no seed/drop (2.53 %) and one seed/ drop (15.43 %) and reasonably low percentage of more than two seeds/drop (26.01 %) as compared to other combinations. The developed precision cotton planter was evaluated in field at an angle of 45º of metering plate with horizontal and a forward speed of 3.0 km/h. The results indicated that field evaluation of developed metering system of precision cotton planter resulted in to 45.10, 27.13, 4.54 and 23.23 % germinated hills as singles, doubles, multiples and missing against the laboratory evaluation results of 15.94, 57.03, 27.01 and 2,53 %, respectively. The percentage of singles, doubles and missing for manual planting were 38.89, 27.78 and 33.33 %, respectively.

Introduction

Cotton planting is conventionally done by manual dibbling. The seeds are sown in lines at a depth of 30 to 40 mm with two seeds per hill maintaining the desired spacing between the rows and plants. The labour requirement for planting cotton seed is high (15 %) next to harvesting operation which consumes 44 % of total labour requirement (Vaiyapuri, 2004). Art of placing seed in the soil to obtain good germination and plant stand without replanting is the ultimate goal of all farmers. A number of factors influence the seed germination and seedling emergence. However, factors important from the performance point of view of the machine include planting depth, uniformity with which seeds are placed, soil compactness around the seeds etc. For the seed placement, various metering mechanisms have been developed and studied by the various researchers.

A tractor drawn multi-crop seed cum fertilizer drill cum planter was developed which could plant 6-rows of groundnut at a spacing of 30 cm in addition to number of other crops like maize, cotton, soybean and sunflower (Kalkat and Chauhan, 1986).

For precise planting, the design parameters from the geometry of roller and brush affect the uniformity of seed placements (Ryu and Kim, 1998). The metering roller designed from such considerations gives a better performance of seed placement. This method can also be applied to the design of metering devices for precision hill dropping for other crops.

The cotton planted with the double-disk opener planter gives

Table 1 The probability of germination for number of seed dropped per hill based on certified germination

Certified Germination (%)	Probability of Germination with Number of Seeds Used		
	One Seed	Two Seeds	Three Seeds
65	0.65	0.88	0.96
70	0.70	0.91	0.97

significantly higher yields as compared with sweep-type planter due to better spacing of plants in the drill row (Metzer, 2002). The cotton planter with its press wheels positioned along the seed row has the greatest level of seedling emergence in a non-crust breaking treatment in a clay loam soil. (Hemmat *et al*., 2003). A multi-power operated planter for planting delineated cotton gives a field capacity and field efficiency of 0.138 ha h-1 and 66.34 %, when operated by bullock power and 0.312 ha h-1 and 68.87 % ,when operated by tractor power, respectively (Kamble *et al*., 2003).

The seed-metering device of a pneumatic planter gives a mean plant spacing of 298 mm in the field with a 19.1 % precision (coefficient of variation). Within a range of plant spacing of 210-300 mm, 49 % cotton plants were distributed compared to 88 % seeds spacing distribution observed on the laboratory test rig. Displacement of seeds in the field due to rolling and bouncing could affect the plant spacing distribution in the field (Singh and Saraswat, 2005). The MAU dibbler gives 86 % more field efficiency than that of hand dibbling method (Vinchi *et al*., 2006). The use of belt type cotton planter for planting cotton resulted in 68.62 and 98.46 % saving in cost and time, respectively, when compared with manual planting (Kamaraj and Kathirvel, 2008).

A heavy pre-sowing irrigation and delayed first irrigation is recommended for better root development and seed cotton yield (Anonymous, 2009). The gap filling by replanting and transplanting do not give satisfactory seed cotton yield. Prior to introduction of Bt cotton hybrids, the sowing of cotton was widely done with the help of seed drills fitted with the fluted roller mechanism comprising of 6-8 flutes. The unsoaked cotton seeds at a rate of 4-5 kg/acre were used for sowing to maintain proper plant population. The introductions of hybrid cotton seeds, which are costly, have necessitated using soaked cotton seeds at a rate of 0.675 kg/acre for maintaining proper plant population. This is not possible with the existing seed drills, as the soaked seed are more prone to damage by the fluted roller metering mechanism. Further, soaking of cotton seeds results in to change in its physical properties (Sharma and Pannu, 2011). The inclined plate metering system has been reported to be best suited for metering soaked okra seed (Sahoo and Srivastava, 2008). So, present study was taken up to develop a seed metering system for planting soaked cotton seeds.

Material and Methods

Development of Metering System

Required number of seeds per drop

The hybrid cotton seeds are known to have a low emergence resistance. Based on probability consideration of the certified germination percentage of hybrid cotton seeds (65 to 70 %), two seeds per hill are to be used in order to achieve a possible 88 to 91 % germinated hills (**Table 1**).

Development of seed metering plate

Based upon the size of water soaked cotton seeds (**Table 2**), an aluminum plate of diameter 150 mm was used to fabricate seed plate (**Fig. 1**) for metering of soaked cotton seed. The design parameters defined by Ryu and Kim (1998)

Fig. 1 The line drawing of the seed metering plate showing various variables

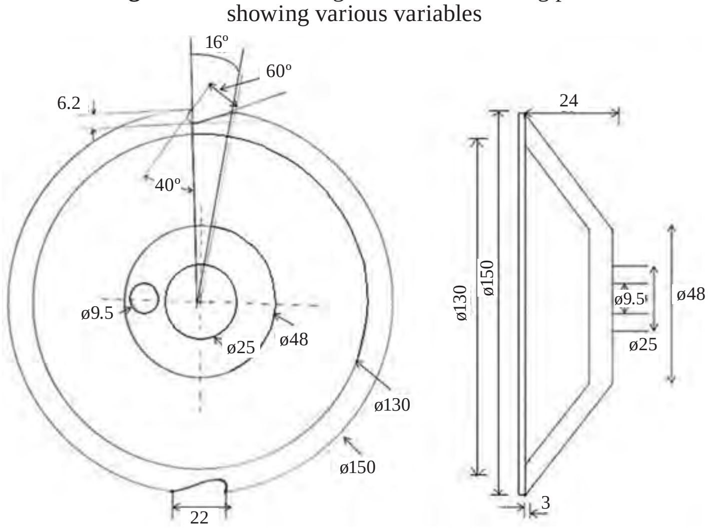


Table 2 The physical properties of soaked cotton seeds

Variety	Length, mm	Breadth, mm	Thickness, mm	Angle of repose, ⁰	Co-efficient of Friction		
					Plywood	GI Sheet	MS
RCH-134	10.82	5.90	4.93	44.70	0.496	0.467	0.508
RCH-317	10.05	5.30	4.68	44.87	0.492	0.445	0.492
7017 BG-II	9.12	5.84	4.76	44.58	0.481	0.447	0.495
MRC-7017	9.76	5.26	4.72	44.47	0.488	0.466	0.498
Mean	9.94	5.58	4.77	44.66	0.489	0.456	0.498

Source: Sharma and Pannu, 2011

Table 3 The values of various variables selected for seed metering plate

Parameter		Purpose	Value
D_g	Depth of the groove	It should be slightly larger than the breadth of seed.	6.2 mm
W	Opening of the grove at periphery	It should be slightly larger than the length of seed.	22 mm
θ_g	The open angle of groove.	It determines the loading process of the groove.	16^0
β_{rs}	The right side angle of the groove	It determines the ease in loading process of the groove.	60^0
β_{rs}	The left side angle of the groove	It determines the seed holding capacity	40^0
R_c	Denotes radius of the curvature of groove bottom	Round groove bottom prevents seeds from clinging to the bottom 22.0 mm	
N	Number of grooves or holes	Plant to plant spacing	2 at 180^0 to each other.

The bottom of the groove was kept round so that the seeds and foreign matter don't clings to the groove.
The bottom of the grove was provided a radius of 1.5 mm.

were considered with certain modifications. The opening of the groove at periphery and depth of the groove were selected on the basis of average length and breadth of the water soaked cotton seeds. The reported average breadth of the soaked cotton seeds was 5.58 mm, so the depth of the groove was selected as 6.2 mm (keeping it 10 % more than the average breadth of the water soaked cotton seed). The average length of water soaked cotton seed was 9.94 mm. Therefore the opening of the groove at the periphery of the plate was kept as 22 mm (keeping it 10 % more than twice the average length of the water soaked cotton seed), such that two to three seeds could be loaded when the groove passes through the seed mass depending upon the orientation of seed. The right angle and the left angle of the groove were selected as 60º and 40º such that easy loading of the groove should be done and as well as the seed loaded in the groove should be retained upto the release point. Two such grooves were made on each seed metering plate at 180º. The different values of the variables selected are given in **Table 3**.

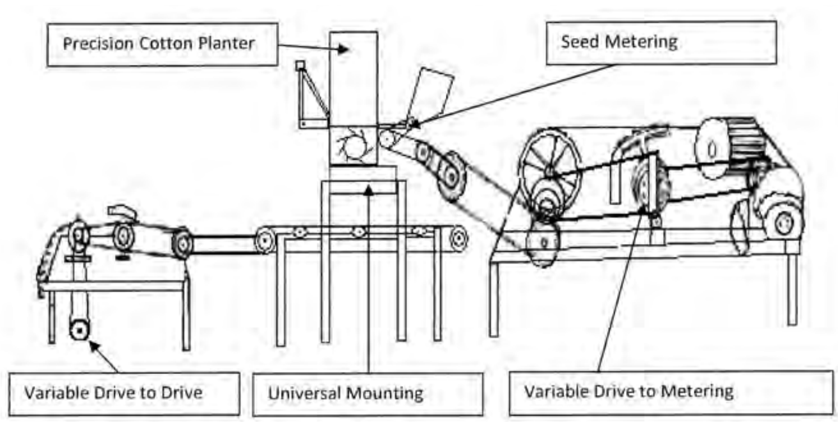
Seed box

Seed boxes were developed for each seed metering plate. In order to avoid frequent filling of seed in the seed box, the seed hopper could be filled once for sowing of one ha of cotton crop. But for proper functioning of seed metering plate, a small quantity of seed should be available on the plates as the placement of large quantity of water soaked seed on seed metering plate of the planter results to its improper functioning. Therefore, seed boxes were provided with baffle plates to maintain the constant flow of seed. The average coefficient of friction as reported by Sharma and Pannu (2011) was lowest (0.456) for GI sheet as compared to MS sheet (0.498), but considering the cost and strength of seed box, 2 mm thick MS sheet was taken for fabrication of seed box. Seed box has two compartments. The main compartment was of 160 × 188 × 240 mm size for storing the seeds. The second (smaller size) compartment holds small quantity of seeds and the inclined plate type metering mechanism was fixed on the slanted wall of this compartment. The seed flow from main compartment to secondary compartment was controlled through a baffle plate to maintain the constant level of seed in second compartment, for proper picking of seeds by the seed metering plate. Two such seed boxes were welded to 31.7 × 31.7 × 3 mm angle irons of 900 mm length on both sides with a bottom support of 50 × 6.5 mm MS flat. This seed box assembly was attached to the supporting frame through bush and the MS shaft of the assembly. A provision to change the angle of inclination of seed metering plates with the horizontal was provided.

Power transmission for seed metering mechanism and furrow opener for seed placement

The power transmission to seed metering mechanism was provided from ground wheel through sprockets, chains and bevel gears for seed metering. The cotton planter with its press wheels positioned along the seed row had the greatest level of seedling emergence (Hemmat *et al.*, 2003). Therefore, shoe type furrow

Fig. 3 Effect of angle of inclination, forward speed and number of seeds per drop on percentage of number of seeds per drop



openers with boot and pneumatic press wheels along the seed row were mounted on supporting frame through diamond shaped clamps for seed placements and covering. The above mentioned seed metering system was used to fabricate a prototype of precision cotton planter.

Laboratory Evaluation of the Metering Mechanism

The angle of repose of soaked cotton seeds is an important consideration for the angle of inclination of seed metering plate. Based upon the angle of repose (45°) of water soaked cotton seeds (Sharma and Pannu, 2011), three levels of angle (i.e. value of angle of repose of soaked cotton seeds and one 50 more and one 50 less than the angle of repose of soaked cotton seeds) were taken. The metering mechanism of the precision cotton planter was evaluated in the laboratory for the seed distribution pattern at three angles of seed metering plate with horizontal and three forward speeds (2.0, 3.0 and 4.0 km/h). The set up being used for testing of seed cum fertilizer drills by the Farm Machinery Testing Centre of the Department of Farm Machinery and Power Engineering was used to evaluate the seed metering mechanism of precision cotton planter. The speed of moving canvas belt of test rig simulates ground speed of PCP with the provisions to vary the speed of operation. The precision cotton planter was mounted on the universal mounting frame of the test rig. The power to operate the PCP was given through gear box, variable drive and set of pulleys. The line diagram of the test rig is shown in **Fig. 2** and view of the set up used to evaluate inclined plate metering mechanism of precision cotton planter shown in **Fig. 3**. The performance of the metering mechanism of precision cotton planter was evaluated in the terms of percentage of number of seeds per drop. The time of seed drop and the number of seeds at each drop (i.e. no seed, one seed, two seeds and more than two seeds per drop) was observed. If the dropping interval was more than 1.5 times of the theoretical interval then it was counted as missing or no seed dropped. This observed data for twenty seed drops for every combination of forward speed and angle of inclination of seed metering plate was recorded with three replications and converted in to percentage for further analysis.

Field Evaluation

The precision cotton planter was operated in wheat harvested field for studying its effect on the germination and its comparison with manual planting using two seeds per hill (**Fig. 4**). The germination count was taken on 14 days after planting for missings (no seed germination), singles, doubles and multiples (more than two seeds germination).

Results and Discussions

Laboratory Evaluation of Metering System

The effect of angle of inclination

Fig. 4 The field evaluation of seed metering mechanism of precision cotton planter

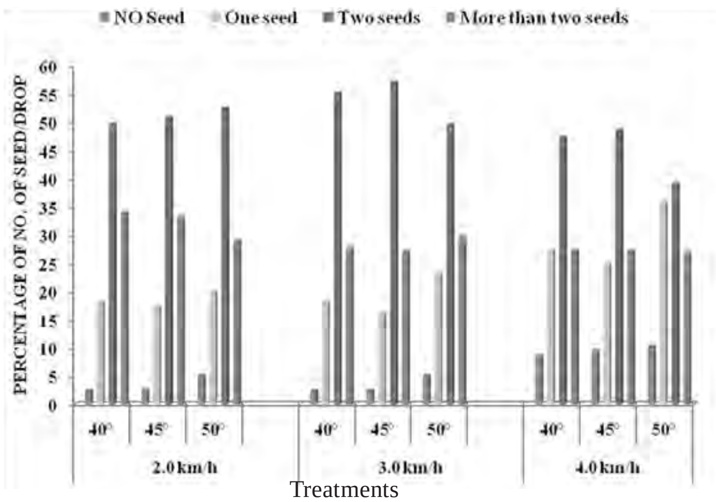


Fig. 2 Line diagram of the test rig used for evaluation of seed metering mechanism

Fig. 3 The laboratory evaluation of seed metering mechanism of precision cotton planter

of seed metering plate (A) and forward speed (B) on number of seeds per drop (C) studied in laboratory is been discussed as below:

Effect of Angle of Inclination of Seed Metering Plate and Number of Seed per Drop on Percentage of Number of Seed per Drop (%)

The angle of repose of soaked cotton seed was around 45º. The angle of seed plate varied above and below this angle to find the number of seeds coming in a one groove at the time of fall. This practice was done due to change of friction between two materials i.e. seed to seed (angle of repose) and seed to metal (inclined seed plate). It is clear from the data (**Table 4**) that the number of seeds per drop in combination with angle of inclination of seed metering plate exhibited the significant difference on percentage of number of seeds per drop. The highest percentage of seed per drop (49.92 %) was recorded with two seeds followed by more than two seeds (29.07 %), one seed (22.26 %) and no seed (5.41 %).

In the combined effect of number of seed per drop and angle of inclination (A), the highest percentage of number of seeds per drop (52.13 %) was registered in case of two seed with the 45º angle of inclination, while it was lowest (4.54 %) with no seed and 40º angle of inclination, however, all the angle of inclination with no seed had non significant difference in respect of the said trait studied. Similar trend was also reported by Chhina (2010) for onion seeds.

The results suggest that the percentage of two seeds/drop tended to increase as the angle of inclination of inclined plate increased from 40º to 45º, and decreased thereafter. Contrary to it, the percentage of one seed/drop decreased with the increase in the angle of inclination from 40º to 45º but followed the increasing trend as the angle increased beyond 50º. The percentage of no seed/drop increased with the increase in angle of inclination from 40º to 50º whereas, the percentage of more than two seeds/drop decreased with increase in angle of inclination from 40º to 50º.

Effect of Forward Speed and Number of Seed per Drop on Percentage of Number of Seeds per Drop (%)

The effect of forward speed (B) and number of seed per drop on percentage of seeds per drop (C) is given in **Table 5**. The highest percentage of number of seeds per drop (49.92 %) was observed with two seeds followed by more than two seeds (29.07 %) and one seed (22.26 %), while its lowest value (5.41 %) was recorded with no seed. The data clearly show that the highest percentage of number of seeds per drop (53.89 %) was noticed with two seeds at the forward speed of 3.0 km/h, however, it was found statistically at par with two seeds at 2.0 km/h forward speed (50.91 %).

The result further indicates that as the forward speed was increased from 2.0 km/h to 3.0 km/h, the percentage of two seed per drop tended to increase from 50.92 to 53.89 %. On further increase in forward speed to 4.0 km/h, it decreased significantly to 44.94 %. The percentage of more than two seeds per drop was decreased significantly from 32.02 to 27.09 % as the speed was increased from 2.0 km/h to 4.0 km/h. Regarding the percentage of one seed per drop, it increased from 18.37 to 29.32 % as the forward speed was increased from 2.0 km/h to 4.0 km/h. Similarly, the percentage of no seed/drop was also increased significantly from 3.39 to 9.47 % as the forward speed was increased from 2.0 km/h to 4.0 km/h. The increase in number of no seed per drop percentage with increase in forward speed might be due to decrease in exposure time of cell to seed in the hopper and also due to more vibration at higher speeds may be the reason which throws the seeds from the cell prematurely. Sahoo and Srivastava (2008) reported that for the soaked okra seeds, the cell speed influenced the multiple index and miss index the most, the least multiple index and miss index was observed to be 3.67 and 2.0 % at the cell speed of 10 rpm while the mean multiple index and mean missing index were 18.71 and 12.48 %, respectively. Similar trend was reported by Sahoo and Srivastava (2008) for inclined plate metering mechanism while using okra seeds.

Selection of the Optimum Forward Speed and Angle of Inclination of Seed Metering Plate

Based on the results obtained and discussed in this section, the following observations have been made regarding the effect of forward speed and angle of inclination of inclined

Table 4 Effect of angle of inclination of seed metering plate and number of seeds per drop on percentage of number of seeds per drop

Angle of inclination (in degree)	Number of seeds per drop* (%)				
	No Seed	One seed	Two seeds	More than two seeds	Mean
40º	4.54	21.15	50.65	29.64	26.50
45º	4.89	19.33	52.13	29.10	26.36
50º	6.80	26.30	46.97	28.46	27.13
Mean	5.41	22.26	49.92	29.07	
$CD_{(0.05)}$					
Angle of inclination (º)(A)					N.S.
Number of seed per drop (C)					2.97
A × C					3.43

*Data Arc-Sine transformation applied

plate with horizontal on percentage of number of seeds per drop.

The percentage of two seeds per drop was highest at an inclination of 45º angle which was close to the angle of repose of soaked cotton seeds. So, an angle of 45º was taken as angle of inclination of the seed metering plate. Similarly a forward speed of 3.0 km/h gave the highest percentage of two seeds per drop showing non significant difference with forward speed of 2.0 km/h. Considering a higher field capacity, a forward speed of 3.0 km/h was selected. Further, it is also evident from the **Fig. 3** that at a forward speed of 3.0 km/h and 45º angle of inclination of seed metering plate with horizontal resulted into highest percentage of two seeds/drop (56.03 %), low percentage of no seed/drop (2.53 %) and one seed/ drop (15.43 %) and reasonably low percentage of more than two seeds/drop (26.01 %). Therefore, an angle of 45º of metering plate and a forward speed of 3.0 km/h were adopted as optimum angle of inclination of metering plate and forward speed for the field operation of precision cotton planter.

Field Performance of Metering System of Precision Cotton Planter

The precision cotton planter was operated in wheat harvested field for determining the seed germination of cotton crop. The data for the field germination was categorized in to singles, doubles multiples (more than two) and missing in a spacing of less than 135 cm (i.e. 1.5 times of the recommended plant spacing). The planting with the developed metering system of precision cotton planter resulted in to 45.10, 27.13, 4.54 and 23.23 % germinated hills as singles, doubles, multiples and missing against the laboratory evaluation results of 15.43, 56.03, 26.01 and 2,53 %, respectively. Similarly, the percentage of singles, doubles and missing for manual planting were 38.89, 27.78 and 33.33 %, respectively (**Table 6**). It was observed that the germination percentage of the precision cotton planter differed from its excepted (91 %) on the basis of probability concept of certified germination percentage (70 %) of cotton seeds. The reason behind this may be the viability of the soaked cotton seed as well as field parameters. But the planting with the precision planter resulted in significantly higher germination percentage probably due to placement of seed at a uniform depth. Kathirvel *et al.* (2005) reported that the percentage of singles, doubles and missing were 59.19, 17.28 and 23.53 % for ridger seeder, 27.1, 6.2 and 66.70 % for pneumatic planter and 50.90, 20.36 and 28.74 %, for cultivator seeder, respectively. Similarly, Kamaraj and Kathirvel (2008) has reported 73.33 % of two plants per hill, 6.67 % of missing hills, while using belt type cotton planter.

Table 5 Effect of forward speed and number of seeds per drop on percentage of number of seeds per drop

Forward Speed (km/h)	Number of seeds per drop* (%)				
	No Seed	One seed	Two seeds	More than two seeds	Mean
2.0	3.39	18.37	50.92	32.02	26.17
3.0	3.37	19.10	53.89	28.09	26.11
4.0	9.47	29.32	44.94	27.09	27.70
Mean	5.41	22.26	49.92	29.07	
$CD_{(0.05)}$					
Forward Speed (B)					N.S.
Number of seed per drop (C)					2.97
B X C					3.43

*Data Arc-Sine transformation applied

Table 6 The number of singles, doubles, multiples and missing hills (%) as observed in laboratory evaluation, field evaluation and with manual planting

Treatments	Singles (%)	Doubles (%)	Multiples (%)	Missings (%)	Total germination (%)
Laboratory Evaluation	15.43	56.03	26.01	2.53	
Field Evaluation	45.10	27.13	4.54	23.23	76.77
Manual Planting	38.89	27.78	0.00	33.33	66.67

Conclusion

1. The forward speed of 3.0 km/h and 45º angle of inclination of seed metering plate with horizontal resulted into highest percentage of two seeds/drop (56.03 %), low percentage of no seed/drop (2.53 %) and one seed/ drop (15.43 %) and reasonably low percentage of more than two seeds/drop (26.01 %) in the laboratory evaluation of the developed metering mechanism.
2. The field evaluation of the developed metering mechanism of the precision cotton planter at the selected forward speed of 3.0 km/h and 45º angle of inclination of seed metering plate with horizontal resulted in to 45.10, 27.13, 4.54 and 23.23 % germinated hills as singles, doubles, multiples and missing.
3. The field evaluation of the developed metering mechanism of the precision cotton planter gave a higher germination (76.77 %) than manual planting (66.77 %) but lower against excepted (91.00 %) as per probability concept of certified seed germination (70.00 %).

REFERENCES

Anonymous. 2009. Package of Practices for cultivation of kharif crops. Punjab Agricultural University, Ludhiana.

Chhina, Ravinder Singh. 2010. Studies on Mechanical Seeding of Onion Seed (Allium cepa L.), unpublished PhD thesis, PAU, Ludhiana.

Hemmat, A., A. A. Khashoei, and I. Ranjbar. 2003. Assessment of irrigated cotton seeding emergence in flatland mechanized planting systems. J Agric. Sci. Tech. 5: 87-98.

Kalkat, H. S. and A. M. Chauhan. 1986. Tractor drawn multicrop seed cum fertilizer drill cum planter. Progress Report of AICRP on FIM, Punjab Agricultural University, Ludhiana Centre: 16-20.

Kamaraj, P. and K. Kathirvel. 2008. Development and evaluation of tractor operated belt type cotton planter J of Agric Engg Res. 45(1): 69-72.

Kamble, A. K., R. H. Rahate, A. A. Deogirikar, L. P. Diwane, and K. P. Arulkar. 2003. Development and evaluation of multipower operated cotton planter. Bioved 14(1/2): 29-32.

Kathirvel, K., Reddy Aravinda, R. Manian, and T. Senthilkuamr. 2005. Performance evaluation of planters for cotton crop. AMA, 36 (1): 61-65.

Metzer, R. B. 2002. Comparison of sweep and double-disk type planter for stand establishment and lint yield. Texas Agric. Ext. Service. http://entowww.tamu.edu/cotton/26.htm cited on 26-05--09.

Ryu, I. H. and K. U. Kim. 1998. Design of roller type metering device for precision planting. Trans of the ASAE, 41(4): 923-30.

Sahoo, P. K. and A. P. Srivastava. 2008. Seed Pattern Characteristics of Different Metering Systems for Soaked Okra Seed. J of Agric Engg, 45(1):1-6.

Sharma Sushil and C. J. S. Pannu. 2011. Effect of water soaking on physical properties of hybrid cotton (Gossypium hirsutum L.) seeds. J of research SKUAST-J.

Singh, R. C., G. Singh, and D. C. Saraswat. 2005. Optimisation of design and operational parameters of a pneumatic seed metering device for planting cottonseeds. Biosys Engg. 92: 429-438.

Vaiyapuri, K. 2004. Studies on inter cropping unconventional green manures in irrigated hybrid cotton. Unpublished Ph. D. thesis. Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore.

Vinchi, R. M., S. N. Solanki, and K. S. Takalgavhankar. 2006. Design and performance evaluation of M.A.U dibbler. J. Agric. Engg. Res 43(2): 43-71.

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Development and Evaluation of Motorized Cowpea Thresher

by

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Abstract

Development of motorized cowpea thresher was conducted based on previous studies. The conceptual, detailed and embodiment design was carried out with Autodesk Inventor Professional 10 software at Cranfield University, UK. The construction and performance evaluation was carried out at Centre for Equipment, Maintenance and Industrial Training (CEMIT) and threshing ground of Federal University of Technology, Yola (FUTY), Nigeria respectively. Quantity used for the performance test ranged from 50 g –250 g of cowpea varieties: indigenous brown (Variety A) and RMP-12 (Sampea -10) white (Variety B). Results showed that the average power requirement, drum speed and design throughput capacity for the motorized cowpea thresher 4.07 kW, 500 rpm and 468kg/hr respectively. The designed feed rate, is 0.5 kg / s, throughput capacity is 468 kg / hr and gross power is 4.0 kW (5.4 hp). Threshing efficiency (Te), Cleaning efficiency (Ce), Mechanical seeds damage (Md), Separation loss (SI), Throughput capacity (QC) and Mechanical efficiency (Ma) were 97 %, 94 %, 1.4 %, 0.9 %, 342 kg/hr & 73 %, respectively. Issues on designs, cowpea threshing and how it can be improved have been discussed.

Introduction

Cowpea (*Vigna unguiculata L. Walp*) is an annual legume which originated from Africa and is widely grown in Africa, Latin America, South East Asia and the Southern United States (Allen and Watts, 1997). Cowpeas, used for human consumption and animal fodder, are rich in protein and the second economic cash crop in Africa after groundnut (Rachie and Singh, 1985 and Dauda, 2001). In Africa, despite the value of cowpea, the methods involved in its production, harvesting and threshing are predominantly manual. Threshing is done using pestle and mortar or by spreading the dried crop on the floor where it is beaten with sticks (Phillips *et al.* 2000 and Oyekan *et al.*, 1990). Although, conventional mechanical threshers such as the Ben–agro paddy thresher, NIAR multi-crop threshers, Alvan Blanch Midget threshers exist (Arnon, 1987), the question is, how suitable are these conventional machines for threshing local crops such as cowpea? Allen and Watts (1998) reported that "a conventional cylinder and concave thresher cannot be used to thresh cowpeas due to the sensitive pericarp of beans and the brittle nature". Furthermore, physico-mechanical properties of crops have to be considered in the conventional machines before the conceptual, detailed and embodiment designs of threshers (Maunde *et al.* 2005).

To thresh cowpea with Alvan Blanch Master multipurpose thresher and reduce mechanical damage, there is the need for pre-threshing before the final threshing of the cowpea with the drum by rubbing action rather than impact action (Maunde, 2008). Despite the increased global importance of design process the ultimate approach is yet to be made. This is because there is a continuous need for new, cost effective and high quality products (Pahl and Beitz, 1984; Ullman, 1997). In the design and production of every product, consideration should be given to the product's impact on the end users, in terms of their accessibility, affordability and comfort. This paper discusses result of a development and evaluation of a motorized cowpea thresher.

Material and Methods

Embodiment design of motorized cowpea thresher has been carried out based on previous work (Maunde *et al*.; 2005, Maunde *et al*.; 2005; Maunde *et al*., 2007) and the results of threshing cowpea with a conventional multi-crop thresher the Alvan Blanch at Cranfield University United Kingdom (Maunde, 2008 & Maunde *et al*., 2009). The following parameters of the thresher were determined: Principal drum parameters which include drum length, drum diameter (for primary and secondary threshing), crop feed rate, drum speed and power required to rotate the drum based on Bossoi *et al*., (1990); Curruthers and Rodriques, (1992). Power transmissions for the motorized thresher were designed based on (Rasnikov, 1991, Aiyeleni, 1993, Osborne, 1977 and Globalspec, 2008). Conveyors and cam-shaker for the motorized thresher were designed using result data from AssoSpring (2006) and Chouhury (1978).

Fig. 1 presents projected view of the motorized thresher. It shows the components and main parts. A primary feeder was introduced in the design which preliminarily performs the threshing function before cowpea passes through the drum and concave at 17 mm entrance and 13 mm exit clearance (Maunde, 2008 and Adewumi *et al*., 2007).

In line with Maunde *et al*., (2010), the motorized cowpea thresher was fabricated and free run tested at CEMIT, Federal University of Technology, Yola, Nigeria. Completed and assembled front view of the said thresher is shown in **Fig. 2**. Full load performance evaluation of the thresher was conducted at the threshing ground of FUTY. 50 g, 100 g, 150 g, 200 g and 250 g of cowpea varieties of indigenous brown (Variety A) and RMP -12 (Sampea -10) white (Variety B) were used for the performance test at moisture content of pods 6.5 % & 6.8 % and of seeds 5.5 % & 6.0 % (Maunde *et al*. 2010). System parameters which included shaft diameter, key type and height, bearing type, width, inner and outer diameter were determined based on calculations (Li *et al*., 2006 and Alonge and Adegbulungbe, 2000).

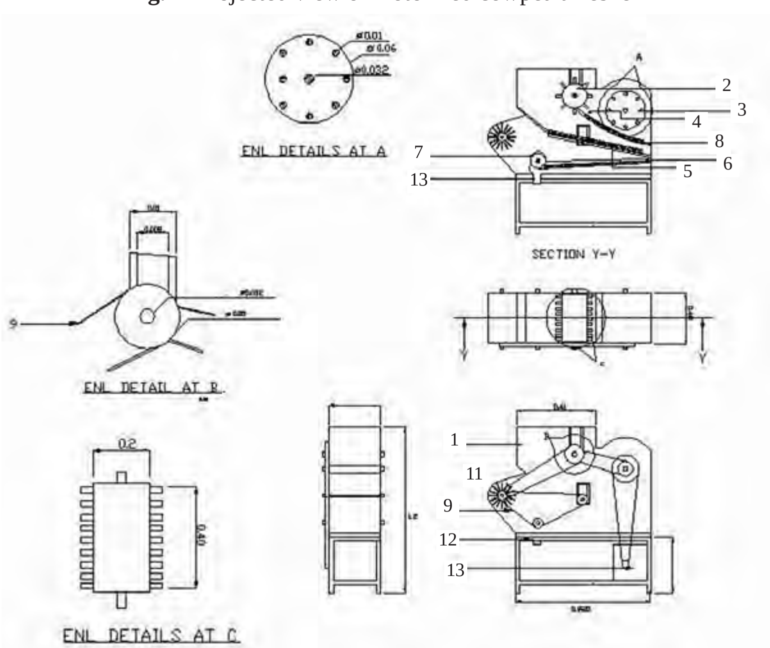
Structural frame which included the hopper design, shape, length, bottom and top width, volume and angle of inclination were designed according to Maunde *et al*. (2007). The stress on the components parts and assembly of the thresher were determined by Inventor version 10 software at Cranfield University Engineering Stadium, Silsoe, Bedfordshire, UK.

Operating Principles of the Motorized Cowpea Thresher

The motorized cowpea thresher is combined:

It does the primary threshing, secondary threshing, cleaning, winnowing, grading and channeling cleaned cowpea into container or sack simultaneously. The height of the motorized cowpea thresher was ergonomically considered to enable the operator fill the unthreshed cowpea into the hopper easily (Maunde *et al*., 2010). The hopper of the thresher is loaded with the unthreshed cowpea half way to prevent compact of the unthreshed cowpea at the feeder and minimum force to primarily thresh the cowpea

Fig. 1 Projected view of motorized cowpea thresher



Legend: 1. Hopper, 2. Feeder (pre –thresher), 3. Threshing drum, 4. Perforated concave, 5. Blower, 6. Shaker, 7. Conveyor, 8. Discharge outlet, 9. Belts, 10. Belts cover, 11. Electric motor, 12. Support frame, 13. chute

Fig. 2 Constructed and tested Motorized cowpea Thresher (Source Maunde *et al*. 2010)

before the secondary threshing at the drum and concave. Immediately after the secondary threshing the blower separates the cowpea chaffs from the seeds while the shaker aids the separation by making gentle up and down movement (almost the same principles with the traditional manual winnowing when the operator throws the mixture of chaffs and seeds on flat tray to allow natural breeze to do the cleaning and separation) (Maunde *et al*., 2007). The conveyor then channels the cleaned cowpea through the outlet chute.

A free rotation test was first carried out on the motorized thresher to establish how it functioned on empty hopper. Afterward, the thresher was tested again under full load of 10 g for each (50. 100, 150, 200, 250) g of cowpea averaged 150 g.

Parameters used for the performance evaluation were as follows:

$T_e = (Q_{tc} + Q_u) / Q_{tb} \times 100$ .... (1)

$C_e = (Q_{tc} + Q_{tf}) / Q_{tb}) \times 100$ ...... (2)

$M_d = (Q_b / Q_{tb}) \times 100$ .... (3)

$S_1 = Q_{tb} - (Q_u + Q_{tc} + Q_b + B_{sf} + Q_{tf})$ .... (4)

$Q_c = Q_{tc} / T_t$ .... (5)

[Ige, 1978].

Where:

T_e = Threshing efficiency (%)

Q_{tc} = Quantity of threshed and clean cowpea (g)

Q_u = Weight of un threshed cowpea after threshing and cleaning (g)

Q_{tb} = Total weight of cowpea quantity before threshing (g)

C_e = Cleaning efficiency (%)

Q_{tf} = Total chaff (kg) {Q_{f1}, whole chaff + Q_{f2}, selected chaff from clean seeds}

M_d = Mechanical seeds damage (%)

Q_b = Quantity of damaged cowpea after threshing and cleaning (g)

S_1 = Seeds / Separation loss (%)

B_{sf} = Blown out seeds and seeds selected from the chaff (%)

Q_c = Actual throughput capacity of threshing (kg / hr)

T_t. = Threshing time (minutes).

However, Mechanical efficiency (Ma), is the ratio of actual output to the design output, thus:

$Ma = QC / QD$ .... (6)

Where:

Ma = Mechanical efficiency of the motorized cowpea thresher (%)

QC = Actual throughput capacity of thresher (g/hr)

QD = Theoretical designed throughput capacity (g/hr).

Table 1 Design Parameters of Motorized Cowpea Thresher

Parameters	
Determined parameters	Calculated values
Length of threshing cylinder and feeder (m)	0.5
Diameter of threshing cylinder (m)	0.38
Diameter of feeder (m)	0.2
Cylinder speed (rpm)	500
Impact force of threshing cylinder (N)	14
Cylinder velocity (m/s)	15
Shaker length (m)	0.55
Feed rate to the cylinder (kg/s)	0.5
Thresher throughput capacity (kg/hr)	468
Diameters of pulley [d1, d2, d3, d4, d5, d6 and d7 (mm)]	42, 260,190,190,100,100 & 100
Resultant tension (N)	653.3
Power required for cylinder and beater (kW)	2.3
Power required for blower (kW)	0.39
Power required for cam shaker (kW)	0.9
Power required for conveyor (kW)	0.51
Gross power requirement (kW)	4.0
Required engine power (hp)	$3 \leq 5$ hp
Shaft type	Solid type
Torque on shaft (Nm)	63.7
Diameter of shaft (mm)	30
Equivalent torque on shaft (Nm)	52
Factor of safety	5.7
Shaft key type	Square key type
Type of blower	Centrifugal type with four blades
Blade length (m)	0.45
Blower average velocity (m/s)	14.3
Total pressure (Pa)	307
Volume flow rate (m^3/s)	1.2
Spring type	Torsion round wire spring
Spring allowable load (N)	450
Number of spring	2
Length of conveyor (m)	0.5
Hopper shape	Combine*
Hopper height (m)	0.41
Hopper top width (m)	0.7
Hopper bottom width (m)	0.54
Hopper volume (m^3)	0.32
Inclination angle (0°)	40
Length of frame (mm)	920
Breadth length (mm)	400
Total frame height (mm)	1200

*Upper part is rectangular and lower part trapezoidal. Source: Maunde *et al.* (2010)

Resulsts and Discussion

Design details of threshing cylinder is presented in **Table 1**.

The length of threshing cylinder, diameter of cylinder, feed rate and designed throughput capacity of the cowpea thresher as seen above have considered for small scale farmers as suggested by Arnon (1987). Power consumption for the motorized thresher agrees with Rasnikov (1991). Based on Chouhury (1978), Li, *et al*. (2006) and Maunde, *et al*. (2009), a combine shaped hopper (upper rectangular and lower trapezoidal) was considered for free flow of cowpeas. From **Table 2** average threshing efficiency of 97 % is similar to threshing efficiency of Ife brown, H 64–3 and IVU–37 cowpea varieties which ranges from 86-96 %; 68-98 % and 81-98 % at drum speed of 300 rpm–550 rpm in all cases respectively (Ige, 1978).

Similarly, average of 1.4 % mechanical seeds damage of the thresher compares favorably well with Allen and Watts (1997) who reported that depending on the amount of cowpea threshed, the amount of broken cowpea should not exceed 15 % of the total weight of threshed cowpea.

However, Dauda (2001), reported that moisture content and mechanical impact on the cowpea crops during threshing were paramount to determining crop damage.

As at December, 2007, the motorized threshers were estimated N 85,800 (naira) equivalent to $700 (US Dollars).

Design details of threshing cylinder is presented in **Table 1**.

Summary process and performance evaluation of thresher is presented in **Table 2**.

Acknowledgements

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REFERENCES

Adewumi, B. A., O. C. Ademosun, and A. S. Ogunlowo. 2007. Design, Fabrication and Preliminary Testing of a Thresher- Cleaner for rain Legume. Journal of Food Science Technology, Vol.44(3) pp. 276-280.

Aiyeleni, U. A. 1993. An evaluation of some parameters relating to cowpea threshing. Nigerian Journal of science. 27: 41-49.

Allen, C. A. W. and K. C. Watts. 1997. Properties of cowpeas (var. Minica beans). International Journal of Agricultural Engineering Research. 68(2): 159-167.

Allen, C. A. W. and K. C. Watts. 1998. Design of a Belt Thresher for Cowpea Beans. AMA. International Journal of Agricultural Mechanization in Asia, Africa and Latin America. 29(3): 42-54. http://sciencelinks.jp/j-east/article/199911/000019991199A0225140.php.

Alonge, A. F. and T. A. Adegbulungbe. 2000. Performance Evaluation of a Locally Developed Grain Thresher –II, AMA, Agricultural Mechanization in Asia, Africa and Latin America, Vol. 31, Issue 2, pp.52-54.

Arnon, I. 1987. Modernization of Agriculture in Developing Countries: Resources, Potentials and Problems. 2nd Edition, John Wiley and Sons, Chichester, pp. 38-45.

Association Spring. 2006. Spring Manufacturer and Designer Spring Barn Group. www.assoc-spring.co.uk. Accessed on 23rd March, 2008.

Bossoi, E. S, O. V. Verniaev, I. I. Smirnov, E. G. Sultan Shakh. 1990. Theory Construction and Calculation of Agricultural Machines. New Delhi, India. 2: 374-389.

Chouhury, M. S. 1978. Threshers: Department of Agricultural Research. Ahmadu Bello University, Zaria. Avan Branch Publisher Nigeria.

Curruthers, I. and M. Rodriques. 1992. Tools for Agriculture: A guide to appropriate Equipment for Small Scale Farmers.4th Edition. Intermediate Technology Publishers Ltd. Southampton Row, London. pp. 115-118.

Dauda, A. 2001. Design, Construction and Performance Evaluation of a Manually Operated Cowpea Thresher for Small Farmers in Northern Nigeria, AMA, Agricultural Mechanization in Asia and Latin America, Vol. 32, Issue 4, pp. 47-49.

Globalspec.com. 2008. Power Transmission Metric Components Catalogue 785. www.globalspec.com. Accessed on 15th August, 2005.

Table 2 Summary of Process and Performance Evaluation of Motor

Parameters considered														
Tests	Qtb (g)	Qtc (g)	Qu (g)	Qb (g)	Bsf (g)	Qtf (g)	SI (%)	Tt (Min)	Te (%)	Md (%)	Ce (%)	QC (g/hr)	# QD (g/hr)	Ma (%)
*XA	150	140	4.3	2.0	1.2	1.8	0.7	25	97	1.3	98	352	468	75
**XB	150	141	4.4	2.3	1.0	1.6	1.1	26	97	1.5	93	333	468	71
AV	150	140.5	4.4	2.2	1.1	1.7	0.9	25.5	97	1.4	94	342	468	73

< Definitions of terms and calculated values was done with equations (1, 2, 3, 4, 5 & 6) and all values are means of 5 replicates (50, 100, 150 200 & 250) g average is 150 g. Source: Maunde *et al*., (2010).
*Cowpea variety A; **Cowpea variety B & AV is average of varieties A & B.

Ige, M. T. 1978. Threshing and Separation Performance of a Locally Built Cowpea Thresher. Journal of Agricultural Engineering Research Vol. 23, pp. 45-51.

Li, K. D., G. Vincent, and L. Zheng. 2006. Universal Accessibility Assessments through Virtual Interactive Design. International Journal of Human Factors Modelling and Simulation. 1: 52-68.

Maunde, F. A., S. M. Yalams, and T. E. Richard. 2010. Design of Manual Cowpea Thresher. In African Journal of Agricultural Research. Vol. 5 No. 12, pp. 1419- 1423. Available online at: http://www.academicjournals.org/AJAR.

Maunde, F. A. 2010. Studies on Selected Postharvest Technological Activities of Women in Adamawa State, Nigeria. Unpublished Ph. D (Agricultural Engineering) Farm Power and Machinery Option. Thesis Submitted to the Postgraduate School Abubakar Tafawa Balewa University Bauchi, Nigeria and to the Registrar Federal University of Technology, Yola, Nigeria.

Maunde, F. A., T. E. Richard, and S. M. Yalams. 2010. Biomechanics Studies of Manual Cowpea Threshing in North-Eastern Nigeria. In Global Journal of Engineering Research India. Vol. 3 No. 1, PP. 149-156.

Maunde, F. A., J. L. Brighton, and H. M. Mohammed. 2009. Study of cowpea threshing with Alvan Blanch Aspra Master. Journal of Engineering Research, Vol. 2 No. 2, pp: 285-291, Global Journal of Engineering and Tech. India.

Maunde, F. A. 2008. Study of Cowpea Threshing with Alvan Blanch Aspra Master and Analytical design of manual and motorized cowpea thresher. Part of Visiting PhD Split –Site Research Report submitted to the Department of Agricultural Engineering, Cranfield University, Silsoe, UK. Unpublished.

Maunde, F. A., M. A. Ali, A. El-Okene, and B. B. Riji. 2007. Determination of Physicomechanical Properties of Cowpea to Aid Thresher Designs. Advanced Material Research. Trans Tech Publication Switzerland. 18-19: 159-164. http//www.scientic.net.

Maunde, F. A., J. N. Maduako, M. A. Ali, and N. Elaija. 2005. Investigation of Physicomechanical Properties of Two Cowpea Varieties. Journal of Agricultural Technology. 13: 31-42.

Maunde, F. A., M. A. Ali, and A. El-Okene. 2005. Appropriate Postharvest Technology in Adamawa State. 1st Edition. Paraclete Publishers, Yola, Nigeria. pp. 311-324.

Osborne, W. C. 1977. Fans. 2nd Edition (in SI/Metric Units). Pergamon Press, Ltd. Oxford, England. pp 6, 14 and 136-140.

Oyekan, P. O., A. Oyekan, A. Adegbulugbe, C. Kwaya, J. Ifem, M. Ajayi-Obe, and A. Lanipekun. 1990. Report on the state of the art of soyabeans threshing in Nigeria.: National Coordinated Research Project on Soyabeans Grant Aided by International Development Research Centre (IDRC).

Rachie, K. O. and S. R. Singh. 1985. Research Production and Utilization of Cowpea. 2nd Edition. Willey Interscience Publication, Great Britain. pp 53-75.

Rasnikov, A. 1991. Fundamental of Designing and Calculating Farm Machinery. 8th Edition Agroprom publishers, Moscow. pp 52-76, 216-220, 321-323 and 616-618.

Pahl, G. and W. Beitz. 1984. Engineering Design. Ken Wallace. Pitman Press, Bath. pp 47, 228-303.

Phillips, R. D., K. H. McWatters, L. R. Beuchat, M. S. Chinnan, Y. C. Hung, R. R. Eitenmiller, S. Sefa-Dedeh, E. O. Sakya-Dawson, Stainer-Asiedu, and A. M. Lartey. 2000. In: Processing and evaluation strategies to increase cowpea utilization. Bean/Cowpea CRSP, Midcourse 2000 Research Meeting, 9th-14th April. Senegal. pp 14-16.

Ullman, D. G. 1997. The Mechanical Design Process. 2nd Edition. McGraw-Hill International Mechanical Engineering Series. pp 24-26, 98, 120-137.

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Does Chilling Water Increase Air Cooling Operation

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Abstract

An Experiment was carried out at the Department workshop of Agricultural Machines and Equipment/ Faculty of Agriculture/University of Baghdad in order to find the effect of adding ice to the cooling material (water). Readings recorded, have been taken out every 10 minutes from 10:10 am to 11 am. The readings included measuring temperature of cooling water in the reservoir and the water temperature before getting out on the pad cooling and temperature dry air to the outside and the temperature of the air after his release from the pads. System was used pad, fan, where you installed the pad at the tip and the fan on the other side of the unit of evaporative cooling, the thickness of pad used 20 cm was set water on the discharge of 10 liters / min designed unit evaporative cooling dimensions (1.2 meters length × 1 meter width × 30 cm thickness) Ground designed and unit restrictions hierarchically directly applicable to the cooling unit, evaporative base of large dimensions (1.17 cm long × 94 cm width) and the remote party (which represents the destination, which ends fan pull air) and narrows the pool to reach its dimensions at the base small (52 cm length × 45 cm width), which ends with a section of a circular hole 37 cm in diameter to stretch and prove at the end of a fan to pull air to the air passes through this section of the ring. The results showed there is no significant difference between treatments at 5 % as it did not affect in addition to the ice water cooling the temperature of the air, but air temperature drops relatively little to be slight

Introduction

The truth is that the cooling produced by an evaporative cooling system is due almost to the evaporation of water into the air and has very little to do with the actual temperature of the water being evaporated. Hot water, cold water, lukewarm water, simply doesn’t matter. The laws of physics say it takes 8,340 Btu’s to evaporate one gallon of water. Therefore, when we evaporate a gallon of water into the air going into a poultry house using either pads or fogging nozzles, 8,340 Btu’s of energy in the form of heat is removed from the air which results in a decrease in air temperature. How much cooling will the evaporation of one gallon of water produce? It depends on the volume of air the gallon of water is being evaporated into; more air less cooling, less air more cooling. But, for example, if we evaporated one gallon of water into 100,000 cubic feet of air each minute, we would reduce the temperature of the air by approximately five degrees. What role does water temperature play in cooling? Again, the laws of physics say 8.34 Btu’s of energy are required to raise the temperature of one gallon of water one degree. So, if in the example above instead of evaporating, lets say, 70 ºF water, we evaporated 15.5 ºC (60 ºF) water, the cooler water would increase the amount of heat had been removed from the air by 83.4 Btu’s (10 ºF × 8.34 Btu’s). What does this all add up to? If it was 32.2 ºC (90 ºF) outside and we have evaporated one gallon of water into 100,000 cfm that would cans we would drop the incoming air temperature to drop to 29.4 ºC (85 ºF). If the water was −12.2 ºC (10 ºF) cooler, the wit incoming air temperature would drop an additional −17.7 to 29.4 ºC (0.05 ºF to 84.95 ºF). Here is an illustration of how much it’s more effective to cool the air through evaporating of water than by using cold water. On a day when it is 32.2 ºC 90 ºF and 50 % Rh a properly designed and maintained six inch pad system will produce approximately −11.6 ºC (11 ºF) of cooling. If the house had 200,000 cfm of exhaust fan capacity, approximately five gallons of water would evaporate from the pads each minute. Now imagine instead of using evaporative cooling pads we ran the incoming air through a large radiator filled with cooled water so the only cooling that took place was due to the heat removed from the air based on the fact that the water is colder than the air (no evaporation). Let's say that the water went into the radiator at a temperature of 15.5 ºC (60 ºF) and exited at a temperature 21.1 ºC (70 ºF) and the air exited into the house at 26.1 ºC (79 ºF) (the same as the pad system). To produce the same −11.6 ºC (11 ºF) of cooling approximately 500 gallons of 15.5 ºC (60 ºF) water would have to flow through the system each mint.

Evaporative cooling is a process in which the sensible heat in the air is used to evaporative water which is in contact with air. The dray temperature is reduced while the humidity of the air being conditioned is increasing. The process is considered adiabatic (no heat gained or lost) because sensible heat is converted to latent heat in the added vapor (Midwest plan Service (MWPS), 1987). Evaporative pad system had a limited using in tunnel-ventilated houses, but the high initial coast of installation has a precluded widespread use of these systems in commercial broiler production. Misting or fogging systems are more spread for cooling broiler in the southeast of USA (Czarick,1988).

Theory

The efficiency of the evaporative cooling process has been expressed by (ASHARE, 1983)

$$E_{ff} = (T_{db} - T_c / T_{db} - T_{wb}) \times 100\ \%$$

Where:

E_{ff} = evaporative cooling efficiency (%)

T_{db} = dry-bulb temperature of unconditioned air (ºC)

T_c = dry-bulb temperature of conditioned air (ºC)

T_{wb} = wet-bulb temperature of unconditioned air (ºC).

When used with pad system, Tdb and Twb are the dray and wet –bulb temperature of the outside air and Tc is the dray –bulb temperature of the cooled air leaving the pad. While this expression is appropriate for evaporative pad system. It does not adequately describe the process that occurs in a broiler house that is being cooled with a fogging system. Occurring simultaneously in this environmental is sensible heating from broiler metabolic heat loss, latent heating from respired moisture (and moisture in the litter).

Procedure

The prototype evaporative cooling system composed of a pad at one end and exhaust fan at the other (**Figs. 1** & **2**).

The prototype measures are 1.2 m× 1 m× 30 cm. A cellulose pad measures are 1.2 m long × 1 m width × 20 cm thickness was mounted in one end of the sheet metal frame. A direct drive, 300mm fan pulled air at speed of 1500 rpm through the pads .water was pumped through pipe over a pad at 10 L/min.

Used Kestrel 3000 pocket weather meter to determine dry and wet bulb temperature of unconditioned air while water temperate determine by Ova meter end with thermogabel as well as temperature of wet air after pads taken by sensor put after pads. The measurements were taken at 10:10 am after ten mints until 11 am. we add ice to water in tank as well as to the top of frame where water is coming by pumping causing it to drop in to pads (**Figs. 3 & 4 & 5**).

Results and Discussion

Table 1 show: Here is an illustration of how much its more effective to cool the air through evaporating water than by using cold water when we add ice to water at 10:10 temperate of water decreases and get 72.77 % cooling efficiency. When adding more ice to water, temperate drop at 10:20 am as well as cooling efficiency drop to reach 60.43 % at time 10:50 while Ice begin to consume and water temperate increases to reach 16 ºC and cooling efficiency

Fig. 1 Fan using in unit cooling

Fig. 2 Cooling units

Fig. 3 Ice in water tank

Fig. 4 Ice in upper tank before water drop in to pads

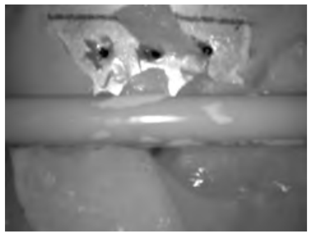
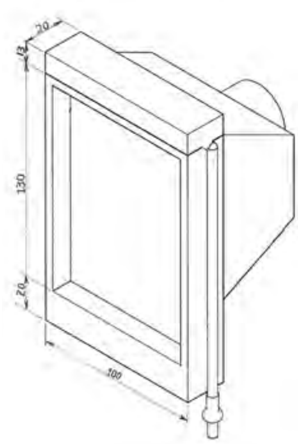


Fig. 5 Cooling Units



increases to reach 71.49 % that's related to Evaporative cooling is a process in which the sensible heat in the air is used to evaporate water in contact with air.

Table 2 shows temperate of water stable through whole time of experiment start with 13.5 ºC at 10:10 am and end with 14 ºC at 11 am while the cooling efficiency is stable between the lower 63.58 % at 10:20 am and the high 70.00 % at11 am that relates to The fact that matter is the amount of cooling produced by a pad system is primarily determined by outside weather conditions.

Conclusions

Trying to increase the amount of cooling produced by a well designed and maintained evaporative cooling system is really a waste of time and effort. The fact that matter is the amount of cooling produced by a pad system is primarily determined by outside weather conditions. For instance, on a 90 ºF when the humidity is 60 % a six-inch pad system will produce approximately 9 ºF of cooling. If the humidity happens to be 20 % lower, the cooling produced would increase to 14 ºF. So do not worry about the temperature of the water in your evaporative cooling system, just make sure your pad is being properly wetted by your distribution system (no dry spots), your houses are tight (so all the air brought into the house is entering through the pads) and hope for dry weather.

Table 1 Measurements taken with add ICE

Time (hr)	Water temp. in tank (ºC)	Dry-bulb (ºC)	Temperate of air after pads (ºC)	Tem. of water under pads (ºC)	Eff. %
10:10	19	37	23.9	12	72.77
10:20	13	36	22.1	9	60.43
10:30	12	37.4	21.3	8	63.38
10:40	14	37.9	22.1	8	66.10
10:50	16	38.1	22.3	11	71.49
11:00	16	38.4	23	11	68.75

Table 2 Measurements taken without adding ICE

Time (hr)	water temp. in tank (ºC)	Dry-bulb (ºC)	temperate of air after pads (ºC)	Tem. of water under pads (ºC)	Eff. %
10:10	13.5	33.5	20.2	10	66.50
10:20	13.5	33	20.6	10	63.58
10:30	13.5	33.3	20.1	10	66.66
10:40	14	33.4	19.9	11	69.58
10:50	14	33.7	20.4	12	67.51
11:00	14	34	20	11	70.00

REFERENCES

Al-Badri, B. Samir. 2008. Study on the Efficiency of pad during day in cooling poultry farm. The Iraqi J. Agric. Sci. 40(3): 108-113.

ASHRAE, 1983. Equipment Handbook. New York: Am. Soc. of Heating, Refrigerating, and Air —Conditioning Engineers.

Bottcher, R. W., G. R. Baughman, R. S. Gates, and M. B. Timmons. 1991. Characterizing Efficiency of Misting System for Poultry. Transaction of the ASAE 34(2): 586-590.

Gray, D. M. 1973. Handbook on the principles of Hydrology. Port Washington, N.Y.: Water Information Center.

Esamay, M. l. 1969. Principle of Animal Environment. Westport Conn.: The AVI Publishing Company, Inc.

Gray, D. M. 1973. Handbook on the principles of Hydrology. port Washington, N. Y. Water information center.

Midwest plan service. 1987. Midwest plan service structures and Environmental Handbook, Rev. 11th Ed. MWPS-1. Ames, Iowa: Midwest plan service.

Timmons, M. B. and G. R. Baughman. 1983. Experimental evaluation of Poultry mist-fog systems. Transaction of the ASAE 26(1): 207-210.

Al-Helal, I. M. 2001. A survey study of cooling pads clogging problem for greenhouses and poultry buildings in central region of Saudi Arabia. Research Bulletin No. 105. Agricultural research center, College of Agriculture, King Saud University. Riyadh, Saudi Arabia.

Al-Helal, I. M. 2002. Water consumption by fan-and-pad evaporative cooling system under arid climate conditions. Arab Universities Journal of Agricultural Science 10(2): 429-440.

Al-Helal, I. M., N. Al-Abbadi, and A. Al-Ibrahim. 2004. A study of fan-pad cooling performance for a photovoltaic powered greenhouse in Saudi Arabian summer. International Agricultural Engineering Journal 13(4): 113-124.

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Development and Performance Evaluation of Virgin Coconut Oil Cooker

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Abstract

Virgin Coconut Oil (VCO) is the highly priced purest form of coconut oil obtained from fresh, mature coconut endosperm by mechanical or natural means, with or without applying heat, but without chemical refining, bleaching or deodorizing. This oil retains the characteristic scent and taste of coconut and is suitable for human consumption without any further processing. One of the different processes involved in VCO production is the hot process wherein the coconut milk is heated to produce coconut oil. A VCO cooker with a capacity of 125 litres per batch has been designed and fabricated for the purpose. VCO cooker is a double walled stainless steel container, which is open in top, with a diameter of 98 cm and a height of 38 cm. Thermic fluid is filled in between the outer and inner walls of the cooker at the bottom and the coconut milk in the cooker gets heated up by hearing the thermic fluid at bottom of the cooker. The VCO cooker could be found suitable for preparation of VCO by hot process by which class A and class B VCO can be produced. The class A virgin coconut oil is water clear having the aroma of steamed coconut. Class B oil is slightly brownish in colour and can be used for external applications. In the present study, fresh and matured coconut was grated and the milk was extracted from the grated coconut using a coconut grating machine and a semi hydraulic milk extractor, respectively. Coconut milk is an emulsion of oil and water that is stabilized by protein. To recover the oil from coconut milk, the protein bond has to be broken either by heat or by enzymes or some other mechanical means. In the present study, the extracted coconut milk was allowed to stand for maximum 3 hours so that the cream could be separated from the skim milk. The cream was cooked in the VCO cooker under controlled temperature till class A oil was obtained. The residue was further cooked to produce class B oil. The capacity of the VCO cooker was found to be 125 litres and it could produce 18.6 litres of virgin coconut in 3 hours cooking time.

Introduction

Virgin coconut oil is the unrefined purest premium grade coconut oil obtained from the fresh and mature kernel of coconut (*Cocos nucifera L.*) by mechanical or natural means with or without the application of heat, which does not lead to alteration of the oil. To protect the oil's essential properties, the production of virgin coconut oil does not undergo chemical refining, bleaching, or deodorizing. Said to be high in vitamins and minerals, it is fit for human consumption without the need for further processing (Villarino *et al.*, 2007). Virgin coconut oil (VCO) is growing in popularity as functional food oil and the public awareness of it is increasing.

Various methods have been developed to extract coconut oil, either through dry or wet processing. Dry processing is the most widely used form of extraction. Clean, ground and steamed copra is pressed by wedge press, screw press or hydraulic press to obtain coconut oil, which then goes through the refining, bleaching, and deodorizing (RBD) processes. During the RBD process, heating process is applied especially during deodorization process, which is carried out at high temperature between 204 and 245 ºC (O' Brien, 2004). The copra industry also faced some problems such as contamination by aflatoxin in copra and cake and presence of high free fatty acids due to high moisture content (Guarte *et al.*, 1996). Recently, there is a trend towards producing coconut oil which does not have to go through the RBD process. Rather than going to the normal dry process, this oil is obtained by wet processing which entails the extraction of the cream from the fresh coconut milk and consequently breaking the cream emulsion. This process is more desirable as no chemical or high heat treatment is imposed on the oil. The coconut oil produced through the wet method is known as virgin coconut oil (VCO).

VCO is generally produced from the coconut milk extracted from fresh coconut. Coconut milk is an emulsion of oil and water that is stabilized by protein. To recover the oil from coconut milk, the protein bond has to be broken either by heat or by enzymes or some other mechanical means. The different processes involved in VCO production are Hot-processing method, Natural fermentation method, Centrifugation process and direct micro expelling method. One of the different processes involved in VCO production is the hot process wherein the coconut milk is heated to produce coconut oil within the shorter period of time when compared to cold process. Virgin coconut oil is prepared conventionally by heating coconut milk in a container at low flame with continuous stirring. It is said that only half portion of a coconut spathe needs to be burned at a time, indicating the requirement of heating coconut milk at a very low flame. It is done manually and the constant stirring is a laborious process. Many a times the milk gets charred and the charred milk stick to the bottom and the sides of the vessel. This happens when the stirring is not proper or when excess fuel is burnt.

In order to avoid these limitations of the traditional Virgin Coconut Oil (VCO) production, a VCO cooker has been designed and fabricated to extract the VCO by hot processing. This paper discusses the development and performance evaluation of this equipment for extracting virgin coconut oil from coconut milk.

Materials and Methods

A virgin coconut oil cooker was designed and developed at the Workshop of Central Plantation Crops Research Institute, Kasaragod, Kerala, India. It is a batch type cooker and is operated mechanically using an electric motor and reduction gear box. VCO cooker is a double jacketed container made of stainless steel. The schematic diagram showing the parts of the VCO cooker is shown in **Fig. 1**.

Thermic fluid is filled in between the outer and inner walls of the cooker at the bottom. Thermic fluid is a mixture of synthetic hydrocarbons and is intended for use in the liquid phase for indirect process heating. It offers increased thermal and oxidation stability that translates in to more efficient heat transfer, longer fluid life and optimum operating economics. It has an optimum economic bulk operating range of −10 ºC to 305 ºC. It exhibits thermal stability markedly superior to that of mineral oils used for the same purpose. Thermic fluid resists the effect of oxidation up to ten times better than mineral oils. Less oxidation means less solids formation and much less fouling.

Proper insulation is provided between the outer and inner walls of the cooker to prevent heat dissipation. A mechanical stirrer is provided in the chamber of the cooker. The stirrer is having four arms. These four mixing arms, together cover the entire bottom and the sides of the stirrer where coconut milk is kept for heating. Contact portions of the stirrer are laminated with Teflon. Teflon is very non-reactive and reduces friction & wear when it comes in contact with moving part. The Teflon coated stirrer is connected to an electric motor (1 hp, 1440 rpm) through a reduction gear (W63/ U P60/B5). An inlet is provided at one side of the cooker to fill the double jacketed vessel with thermic fluid. An expansion tank (17.5 cm dia and 45 cm height) is also provided at the inlet. The expansion tank makes it easy to pour the thermic fluid and also helps to monitor the oil level in the cooker. A pressure release valve that acts as a safety valve is provided to the thermic fluid chamber to release the pressure build up, if any, occurs in it. An industrial, dial type, thermometer is provided in the thermic fluid chamber to monitor the temperature of the thermic fluid. An outlet is provided at the bottom of the milk chamber to take out oil. A three inch diameter outlet valve with a rubber washer to make it leak proof is provided in the bottom of the milk container. The outlet valve is opened and closed manually using a lever. Two LPG burners are pro-

Fig. 1 Schematic diagram of Virgin Coconut Oil Cooker

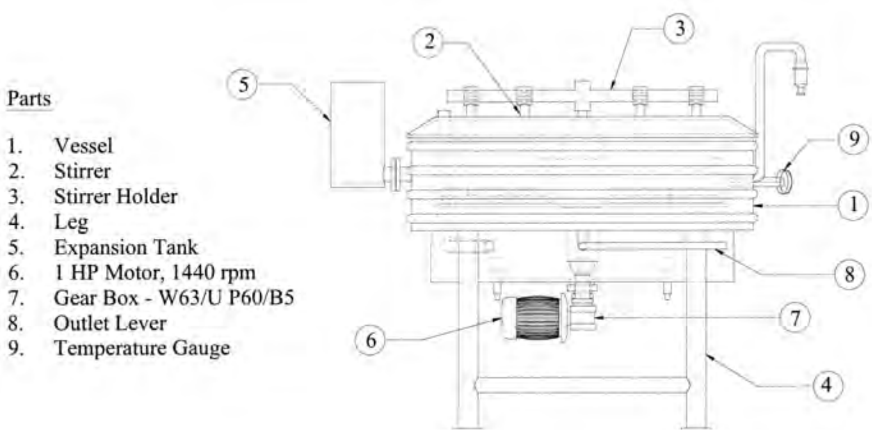


Table 1 Design details of the VCO cooker

Parameter	Dimension
Milk container diameter	Inner dia − 95 cm Outer dia − 109 cm
Milk container height	24.5 cm
Material used for milk vessel/container	Stainless steel-food grade
Milk container thickness	20 gauge
Stirrer arm	4 no.
Stirrer speed	25 rpm
Motor	1 hp, 1440 rpm
Legs	4 No.
Expansion tank	17.5 cm dia and 45 cm height

vided at the bottom of the cooker to heat thermic fluid chamber directly and in turn the thermic fluid chamber heats the bottom of the milk container. The entire cooker is supported by four legs. The schematic diagram showing the front and side view of the newly developed VCO cooker is shown in **Fig. 2**.

Power requirement of mixing arm

The horse power of motor required to rotate the mixing arm was calculated by using the following formula suggested by Khurmi and Gupta (2006).

Power required, hp = 2πNT / 4500

where,

hp = horse power of motor

N = RPM of the mixing arm

T = torque, kg-m

Self weight of the mixing arm = 6 kg

Coconut cream / milk to be mixed = 125 kg per batch

Speed of the mixing arm (assumed) = 25 rpm

∴ *Coconut cream to be mixed per revolution = 40 kg*

Total weight

= self weight + material weight

= 6 + 40 = 46 kg

Torque required

= Load × Distance

= 46 × 0.60 = 27.6 kg^{-m}

(Distance = contact distance in the container where the mixing is done = 0.60 m)

∴ *hp = (2 × 3.14 × 25 × 27.6) / 4500*

hp of motor required = 0.963 ≅ 1 hp

The design details of the developed VCO cooker are illustrated in the **Table 1**.

Working of VCO Cooker

Coconut milk was extracted from fully matured coconuts. The extracted coconut milk was poured in to the VCO cooker. Though, the cooker could be filled full, for operational convenience it was filled only up to 3/4 th capacity. The reason was to avoid any possible splashing when the stirrer is stopped and restarted in between operation. The cooker could be ignited even before loading. The cooker was heated by igniting the gas burners. The burners were burnt with full flame initially. After attaining the required temperature it was reduced as per requirement and quantity of coconut milk. Coconut milk was heated in the cooker till all the water gets evaporated and oil gets separated. The flame was reduced to minimum and finally it was switched off towards the end of the process. The separated oil and the residue, Kalkam, were taken out by opening the outlet.

The oil recovery was calculated as per the following formula.

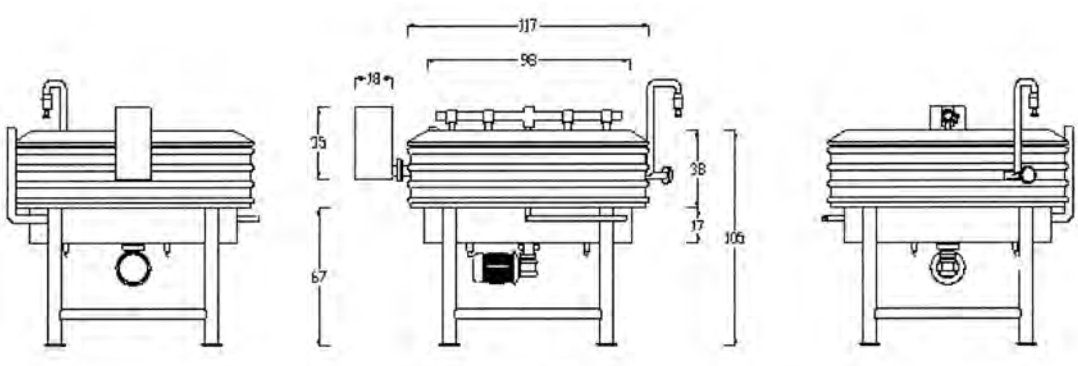
Oil Yield (%) = (Quantity of VCO obtained / Total quantity of coconut kernel) × 100

Results and Discussion

A Virgin Coconut Oil cooker was developed and evaluated for extracting virgin coconut oil from coconut milk. **Fig. 3** shows the working of the newly developed VCO cooker for extracting VCO from coconut milk.

Coconut milk was extracted from fully matured coconuts. Virgin coconut oil can be extracted from the milk by two different ways. Fresh coconut milk can be directly poured in to the cooker and it can be heated for extracting the oil. In the other method, coconut milk is allowed to settle for 3 hours to separate the skim milk from the cream. If the settling is done under refrigerated condition the time taken is only 1 hour and coco skim milk which is a nutritious beverage

Fig. 2 Schematic diagram showing front view and side views of Virgin Coconut Oil Cooker



All dimensions in cm

containing protein and micronutrients can be recovered for human consumption (Bawalan, 2003). The coconut cream is further separated from the skim milk and can be heated in the specially designed VCO cooker under controlled temperature to extract virgin coconut oil. The double walled VCO cooker under slow heat coagulates the protein and release the oil. Heat was provided through LPG by heating the thermic fluid chamber. Temperature was monitored and accordingly the heat was regulated. A mechanical stirrer is provided to stir the milk to avoid the cream sticking to the bottom. For the first hour of heating, temperature was allowed to reach 120 ºC. Further the temperature was brought down to 90 ºC until the protein begins to coagulate and the temperature was reduced to 70 ºC when the oil starts to separate. The temperature profile of thermic fluid and coconut milk during hot processing in VCO cooker is given in **Fig. 4**.

Oil was separated from the oil residue (kalkam) by straining the mixture through a stainless steel screen with fine mesh. This oil was colourless, transparent and with pleasant aroma and is known as class A oil. The remaining residue 'kalkam' was brown in colour and was further heated at a temperature of 80 to 90 ºC so that maximum oil could be recovered. This oil was slightly dark in colour and is known as class B oil and is suitable for skin care and massage purpose. Total time taken for cooking was about 2.5 hours for extracting class A VCO and the timed required to extract class B VCO was 3 hours. The cream temperature at which the class A Oil started to separate was 90 ºC where as the thermic fluid temperature was 170 ºC during the class A oil separation. After collecting the class A oil, Subsequently the thermic fluid temperature was reduced to maintain the cream temperature at 100 ºC to extract class B oil. Class A and class B oil were separately dried /heated to remove the moisture completely so that the shelf life of the VCO could be enhanced upto 1 year. The VCO yield obtained was 18.6 %.

Conclusion

A Virgin coconut oil cooker with a capacity of 125 litres of coconut milk per batch was developed. Premium quality virgin coconut oil could be extracted from coconut oil by hot process method utilizing the newly developed VCO cooker and the oil recovery was around 18.6 % in three hours processing time.

Acknowledgement

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REFERENCES

Bawalan D. D. 2003. Coconut processing modules for micro and village scale enterprises, proceedings of the XLCOCOTECH meeting, Colombo (Ed. P. Rethinam), APCC, Jakarta, Indonesia.

Khurmi, R. S. and J. K. Gupta. 2006. A textbook of machine design. Eurasia Publishing House (Pvt.) Limited, New Delhi.

O'Brien, R. D. 2004. Fats and oils: Formulating and processing for applications, CRC Press, New York.

Villarino, B. J., L. M. Dy, and C. C. Lizada. 2007. Descriptive sensory evaluation of virgin coconut oil and refined, bleached and deodorized coconut oil. LWT-Food Science and Technology 40, 193-199.

Guarte, R. C., W. Muhlbauer, and M. Kellert. 1996. Drying characteristics of copra and quality of copra and coconut oil. Postharvest Biology and Technology 9, 361-372.

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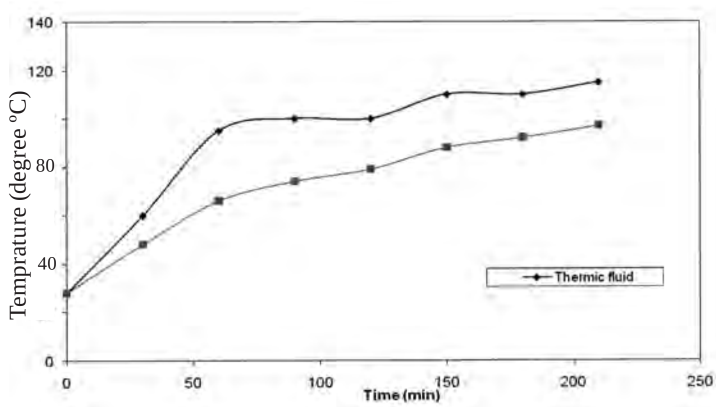
Fig. 3 Working of newly developed VCO cooker

Fig. 4 Temperture profile of thermic fluid and coconut milk in VCO cooker



Study on Sinkage and Rolling Resistance of Various Tractors in the Soil

by
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Abstract

Performance of off road vehicles like tractors, power transmission due to soil tyre interaction is generally inefficient resulting in losses of millions of litters of fuel. In this regard an attempt has been made to get the information on sinkage at various loadings and rolling resistance of various tractors in different soils. Three different soils, at various locations were considered and tests were conducted on sinkage at various loadings. The moisture contents were also changed for these three types of soils. Tractor parameters like –tyre diameters, tyre widths, etc. were measured. It was found that diameter of rear tyre was in the range of 1270 mm to 1440 mm and width 240 to 320 mm. Sinkage decreased with decrease in moisture content of soils, whereas, rolling resistance varied with change in type of soil and moisture content. Rolling resistance was in the range of 11.7 kN to 18.4 kN, 13.1 kN to 20.6 kN and 5.1 kN to 8.2 kN for three different soils and similarly it varied with various tractors.

Introduction

Ever increasing demand of food production to feed the rising population has tremendously increased the use of fertilizer, irrigation, improved varieties and tractorization etc. in production agriculture. With the introduction of high yielding varieties, intensive cropping pattern, increased use of fertilizers and chemicals and high level of mechanization and tractorization, the modern agriculture has become energy intensive. Tractors are the major constituent of farm mechanization, which have several objectives to increase the productivity per agricultural worker, making farm operations easier and more attractive and similar others. There is an observation that there is serious loss of traction in the light soils of Punjab and other parts of country resulting in loss of tractor power and inability of the tractor to handle heavy jobs in the field as traction tends to be limiting factor. Thus this loss of power, time and machine capacity as a result of poor traction, if converted into rupees, would amount to huge sum for India.

The soil-tyre interaction yields higher stresses at the soil-tyre interface, which causes soil compaction. The compaction of soil due to traction leads to decreased pore space in the soil, due to which water retention capacity decreases causing reduction in root and plant growth and in turns crop yield. The soil compaction is not desirable in tillage or agricultural practices. The common causes of agricultural soil compaction in fields are due to trampling by live stock and pressures imposed by vehicles or tillage implements. The extent of soil compaction by farm vehicles is related to soil type, soil moisture and the number of passes and contact pressures of machinery traffic. Changes in soil strength and the soil-air-water contents are some of the effects of soil compaction.

The agricultural fields are often trafficked during tilling which causes the compaction problem in many agricultural soils. Due to compaction, its bulk density increases making soil more packed. Increased bulk density reduces porosity and can affect plant growth . Generally due to compaction there is a rut formation by equipment over to the soil surface and affects the sowing and plant growth. Therefore, the present study was taken up with the objectives to study the sinkage at various loadings and the rolling resistance of various tractors in different soils.

A three-D finite element model was developed by Chi *et al.* (1993), to predict the soil compaction. The finite element results indicated that reused airplane tires with high inflation pressure resulted in the worst soil compaction, while an agricultural high floatation tire with a smaller load and lower inflation pressure caused the least soil compaction. Further, the soil compaction can be reduced by using lower tire inflation pressure. Adam and Erbach (1995) developed a relationship between tire sinkage depth and depth at which traffic increased bulk density by 0.05 mg/m^3. An oval metal plate 100 mm wide and 122 mm long was used to apply stresses of 25, 50, 100, and 150 kPa to soil. Different tire inflation pressures and loads were used to create different tire sinkage depths. Differences in bulk density were used to determine depth at which applied stress caused significant soil compaction. Compaction depth, Y, was found to be related to sinkage depth, X, by the empirical equation, $Y = bX^m$ where b and m are regression constants. Sharma and Pandey (1997) analyzed the effect of normal load on drawbar performance of three traction tyres (11.2-28, 12.4-28 & 13.6-28) that were most commonly used in Indian tractors (up to 50 hp). The tests were conducted in sandy clay loam soil within 18-26 % tyre deflection and 740-1780 kPa soil cone index. The study revealed that regression models for various performance parameters can be used to predict drawbar performance of the tyres under field conditions. Three directional contact stresses at three locations on a lug of a pneumatic tractor tire in a completely soft rotary-tilled soil overlaying a hardpan about 250 mm below the surface was investigated by Jun *et al.* (1991), Increased dynamic load increased the levels of stresses. The maximum normal stress occurred near the tire centerline at high inflation pressure. The maximum tangential stress occurred near the tire centerline and decreased as the position moved from the tire centerline to the edge of the tire.

Materials & Methods

The equipment and methodology used in the study along with various tractor and soil parameters were as given below.

Tractor Parameters

The number of tractor parameters were included in the study, i.e., name of tractor, make of tractor, horse power of tractor, tractor tyre diameters, tractor tyre radius for both front and rear tyre, tyre width, tyre size for both front and rear, wheel base, weight of tractor, type of ballast ,if any, weight of ballast, overall dimensions i.e. length, width, height of tractor. All these parameters were observed by developing an observation sheet.

Diameter, Width and Size of Tyre

The tractor tyre diameter of the rear tyre was measured using tyre gauge, **Fig. 1**. The tyre diameter of the front tyre was measured using a smaller length tyre gauge, whereas, the diameter of rear wheel was measured with help of larger gauge. The tyre width was measured by taking impressions of the tyre on sheet of both front as well as rear tyre and then measuring the width of the impressions on the sheet. The tyre size was observed as mentioned on the tyres. It gave the inner tyre diameter and the tyre width ply rating.

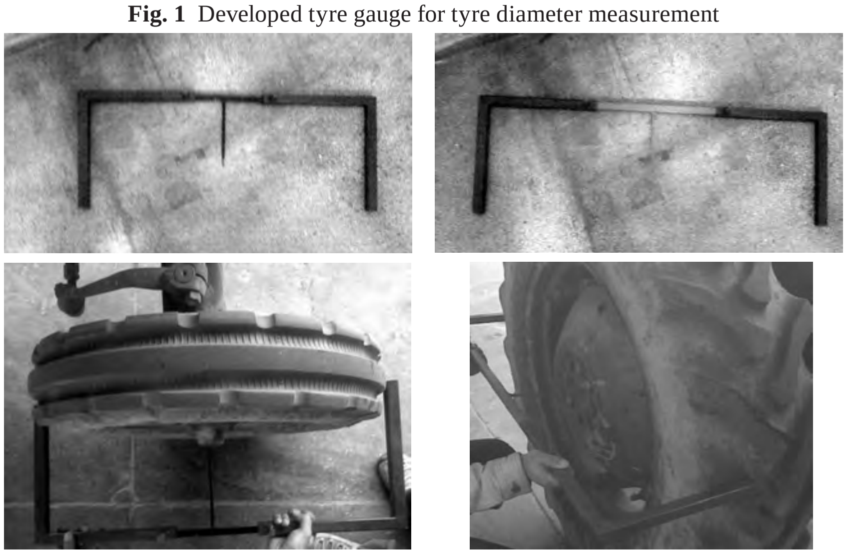
Development of the Tyre Gauge

The tyre diameter and tyre radius was measured by developing a tyre gauge. The tyre gauge was made up of simple MS pipe. In this a MS pipe of length more than 900 mm was taken and a pointer rod was welded at its centre. Then two pipes of 300 mm were welded to each other at right angles of L shaped. Two such frames L shaped pipes were made for attaching it both sides of the 900 mm pipe and 450 mm pipe. Both the frames had a tightening screw at their ends. The pointer was kept at middle of the tyre and diameter was measured within the two L shaped pipes

Weight and Ballast of Tractor

The weight on the front tyre and weight on the rear tyre was determined by using weigh bridge type of balance. The total weight of the tractor was also measured using the weighing balance and compared with the weight given by the manufacturers. The ballasting was generally done to increase the traction of the tractors, which was of two types i.e. water ballasting and adding weights to the tyres. Tractors were checked for ballasting of either type

Fig. 1 Developed tyre gauge for tyre diameter measurement



which was an observation.

Soil Parameters

The experiment was conducted on irrigated soil which was tested for taking samples from three different locations.

Moisture Content

The soil moisture content was determined using oven drying method in which the soil sample was taken in small box, and the weight of box was determined then the weight of soil and box together were taken. Then box was kept in the oven for drying and hence moisture content was found.

Sinkage

On applying the pressure on to the soil there will be sinkage. The sinkage may be affected by compaction and moisture of soil. Therefore, sinkage was measured in different types of soil and at varying moisture contents.

The Sinkage Measurement with Tripod Equipment

In the tripod type of equipment there was a vertical rod passing through the centre of the tripod equipment. At the end of the rod, there was a O-ring (Loading ring) for measuring the load applied on to the soil, **Fig. 2**. The tripod equipment was made stable with the three weights kept at three corners of the equipment, **Fig. 2**. The loading ring was attached with a rod at the end and there was a plate which was kept between the soil and the lower end of rod. On rotating the screw, plate was pushed into the soil and the readings were observed with the help of dial gauge.

Fig. 2 Tripod Equipment and Loading Ring for Sinkage measurement

Calibration of Loading Ring

A loading ring was calibrated by taking reading of it using only O-ring and few weights. The loading ring was applied with various known loads, one after the other and the reading were observed from dial gauge and were recorded. It was repeated thrice to calibrate the ring.

Rolling Resistance

The bearing strength was mainly affected by depth of sinkage. The equations used for evaluating the sinkage of foundation footings did not hold good to predict the relationship between applied load and sinkage underneath a vehicle moving off-the road for the reason that the relative magnitude of permissible sinkage and the time for sinkage to occur greatly differ.

Basic equation (1978, 2000) used was

$P_z = KZ^n$

Which was modified as-

$P_z = KZ^n [(Kc/b) + K\Phi]$

Kc, KΦ and n are means of accessing the composite property, bearing strength.

where-

P_z = Pressure in the direction of sinkage

Kc = Cohesive modulus of soil deformation

KΦ = Frictional modulus of soil deformation

b = width of plate

n = Constant, sinkage exponent

To determine the rolling resistance due to compaction underneath a pneumatic tyre of a tractor it was necessary to take tyre foot print and to measure its dimensions.

To determine rolling resistance 'R' the following equation was used

$R = (A / B)$

Where

$A = (3W / D^{0.5})^{(2n + 2) / (2n + 1)}$

and

$B = [3 - n]^{\frac{(2n+2)}{(2n+1)}} (n+1)(Kc + bk\phi)^{\left(1/2n+1\right)}$

R = Rolling Resistance, N

D = Diameter of the wheel, driving tyre

W = Weight of the tractor

b = width of tyre foot print

The tripod equipment was put on leveled pulverized soil and the weights were put on the three foot rest of the equipment to make it stable. The rectangular plate (R_p)was chosen and placed under the loading ring. The upper handle was rotated in clockwise direction and readings were noted after every 90° rotation and till the readings were possible with the setup. Then similar procedure was followed for the circular plate (C_p) instead of rectangular plate at the three different locations. Black oil was applied on the tractor tyre and then white sheet was placed under the tyre and the tractor was moved over the sheet such that oiled portion came over to the sheet. Tractor was moved back and sheet was lifted. Foot prints dimensions were measured, viz. width and length.

Results and Discussion

Some important results were discussed as under at different moisture contents of soils.

Table 1 Various tractors and tyre diameters

Tractor	Tyre size	
	Fore wheel Diameter, mm	Rear wheel Diameter, mm
Tr_1	915	1440
Tr_2	700	1270
Tr_3	700	1270
Tr_4	700	1270
Tr_5	700	1270
Tr_6	800	1440
Tr_7	800	1440
Tr_8	915	1440

Tractor Parameters

The tractor tyre diameters were measured using tyre gauge for front and rear wheels. The front wheel diameter was found in the range of 700 mm to 915 mm and similarly rear tyre diameter ranged form 1270 mm to 1440 mm, **Table 1**, tyre width was varying for rear tyre from 240 mm to 365 mm for various studied tractors, where as, it was 132 mm to 154 mm for forward wheel. The tyre size for front tyre were in the range of 6.00-16 to 7.50-16 and for rear tyre it ranged from 12.4-28 to 16.9-28. The wheel base of various tractors was also measured which ranged from 1830 mm to 2210 mm. These tractor were also observed for ballasting done, if any, and none of the tractor was found with ballasting. There was a lot of variation in the weight of tractors which was ranging from 15 KN to

Fig 3 Sinkage at Various Loadings of two Plates at Soil S_1 and moisture Content M_1

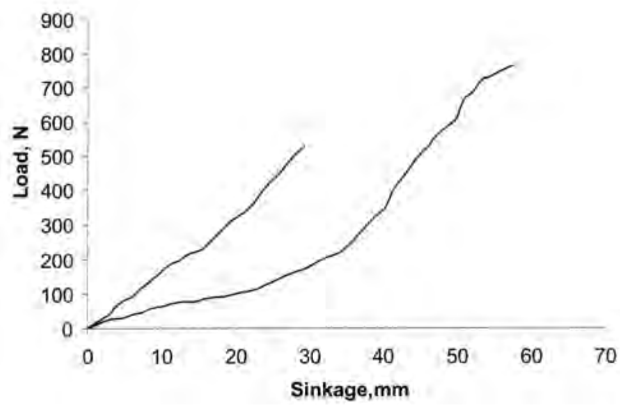


Fig 4 Sinkage at Various Loadings of two Plates at Soil S_1 and moisture Content M_2

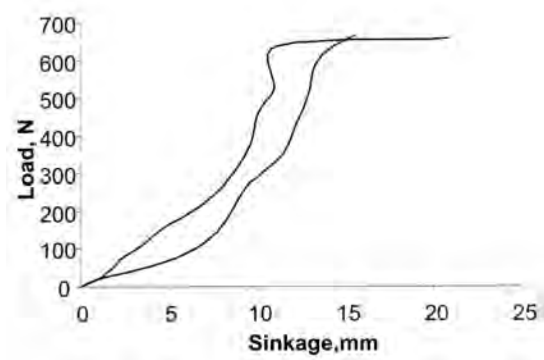


Fig 5 Sinkage at Various Loadings of two Plates at Soil S_2 and moisture Content M_1

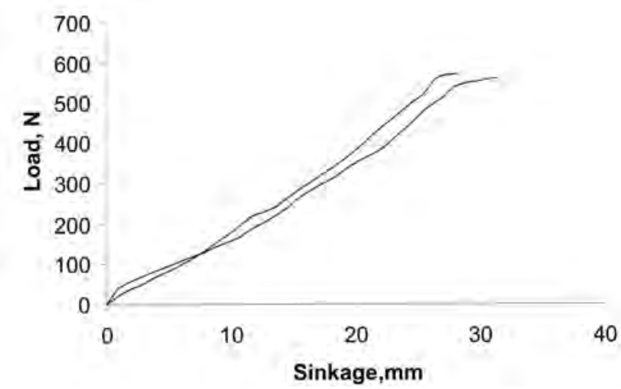


Fig 6 Sinkage at Various Loadings of two Plates at Soil S_2 and moisture Content M_1

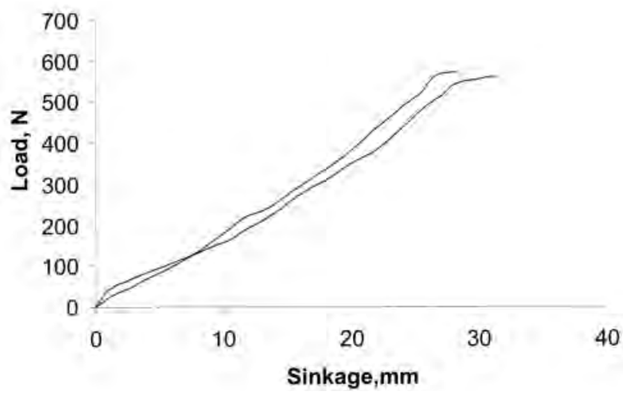


Fig 7 Sinkage at Various Loadings of two Plates at Soil S_2 and moisture Content M_2

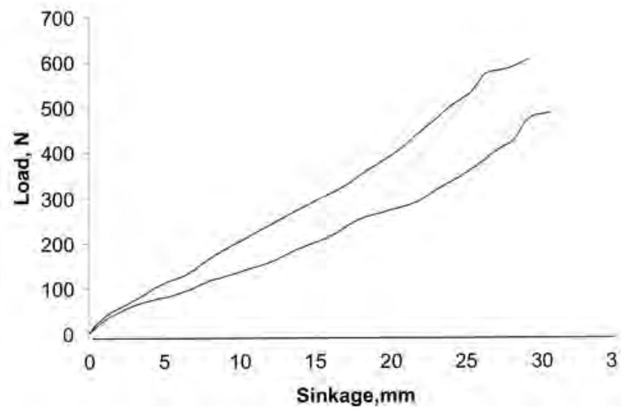
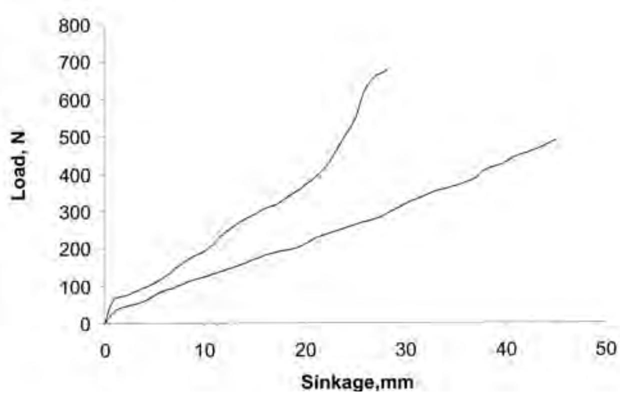


Fig 8 Sinkage at Various Loadings of two Plates at Soil S_3 and moisture Content M_2



24.5 KN.

Sinkage at Various Loadings

Sinkage of soil for two plates round (C_p) and rectangular (R_p) were studied in three different soils S_1, S_2 and S_3 at two moisture content of soil M_1 and M_2. It was found that the sinkage was different for both the plates in all three soils and two moisture contents. It was due to variation in width of plate. Further it was found that at moisture content M_2 the sinkage was different than the moisture content at M_1 for all three soils S_1, S_2 and S_3, **Fig. 3**, **Fig. 4**, **Fig. 5**, **Fig. 6**, **Fig. 7** and **Fig. 8**. In general there was a decreasing trend from moisture M_1 to M_2. Soil pressures were also varied with variation in soil from S_1 to S_3 and moisture content M_1 to M_2, **Table 2**, **Table 3**. The sinkage varied from 1.4 mm to 57 mm and 1.83 mm to 29 mm for the applied loads 15.6 N to 769 N and 26 N to 529 N respectively for plates (R_p) and (C_p) at soil S_1 and moisture content M_1. Similarly soil pressure varied from 0.31 N/cm^2 to 15.15 N/cm^2 for plates (R_p) and (C_p). Similarly it varied in all the three soils and two moisture content, **Table 2** and **Table 3**.

Table 2 Average Sinkage at Various Loadings at Soil S_1 Moisture Content M_1

Sinkage, mm		Applied Load, N		Soil Pressure, N/cm^2	
R_p	C_p	R_p	C_p	R_p	C_p
0	0	0	0	0	0
1.4	1.8	15.69	26.16	0.31	0.32
2.86	3.13	26.16	47.09	0.51	0.58
4.43	4.4	28.78	73.26	0.56	0.91
5.9	5.8	39.24	88.95	0.77	1.11
7.4	7.06	47.09	115.12	0.93	1.43
8.83	8.4	60.17	136.05	1.19	1.69
10.36	9.7	65.41	159.60	1.29	1.99
11.86	11	73.26	183.15	1.45	2.28
13.4	12.43	78.49	196.23	1.55	2.44
14.96	13.76	81.10	217.16	1.60	2.71
16.46	15.23	88.95	227.62	1.76	2.84
18.03	16.53	91.57	251.17	1.81	3.13
19.56	17.8	96.80	277.34	1.91	3.46
21.06	19.03	104.65	306.12	2.07	3.82
22.56	20.36	112.50	327.05	2.22	4.08
24	21.7	125.58	347.98	2.48	4.34
25.43	22.93	138.67	376.76	2.74	4.70
26.83	24.1	154.36	410.77	3.05	5.12
28.3	25.6	164.83	439.56	3.26	5.48
29.73	26.75	177.91	474.88	3.52	5.92
31.13	28	193.61	502.35	3.83	6.27
32.55	29.25	208.00	529.82	4.11	6.61
34		219.78		4.35	
35.3		243.32		4.81	
36.53		272.10		5.38	
37.76		300.88		5.95	
39		329.67		6.52	
40.3		353.21		6.99	
41.3		400.31		7.92	
42.46		434.32		8.60	
43.63		468.34		9.27	
44.8		502.35		9.94	
46.06		528.51		10.46	
47.23		562.53		11.13	
48.53		586.08		11.60	
49.8		612.24		12.12	
50.76		661.95		13.10	
52.03		688.12		13.62	
53.2		722.13		14.29	
54.63		735.21		14.55	
56.03		750.91		14.86	

Rolling Resistance

The rolling resistance of various tractors in different soils at two moisture contents were found. For tractor T_1 rolling resistance was in the range of 5185 to 14369 N for three soils S_1, S_2 and S_3 with two moisture content M_1 and M_2. The rolling resistance of T_2 was in range of 7477 to 19810 N for three soils S_1, S_2 and S_3 with two moisture content M_1 and M_2. The rolling resistance of T_3 was in range of 4769 to 13159 N for soils S_1, S_2 and S_3 with moisture content M_1 and M_2. The rolling resistance of T_4 was in range of 5732 to 15627 N for soils S_1, S_2 and S_3 with moisture content M_1 and M_2. The rolling resistance of T_5 was in range of 6066 to 16133 N for soils S_1, S_2 and S_3 with moisture content M_1 and M_2. The rolling resistance of T_6 was in range of 6592 to 17482 N for soils S_1, S_2 and S_3 with moisture content M_1 and M_2. The rolling resistance of T_7 was in range of 6172 to 16635 N for soils S_1, S_2 and S_3 with moisture content M_1 and M_2. The rolling resistance of T_8 was in range of 7476 to 20593 N for soils S_1, S_2 and S_3 with moisture content M_1 and M_2. Therefore, rolling resistance varied with tractor and also with type of soil, might be due to variation in their weights, wheel diameters, width of the wheels and soil parameters.

Conclusions

The rear and forward wheel diameters of various tractors ranged from 1270 to 1440 mm and 700 to 915 mm respectively and similarly the size of tyres also varied. The sinkage of soil was decreased with decrease in moisture content, where as, soil pressure in the direction of sinkage of the two plates varied with variation in the soil moisture content. The rolling resistance changed with variation in soil and which was in the range of 11690 N to 18425 N, 13160 N and 5190 N to 8220 N for the soils studied, for the different makes of tractors.

Acknowledgement

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REFERENCES

Adam, K. M. and D. C. Erbach. 1995. Relationship of sinkage depth to the depth of soil compaction. Trnas. of ASAE 38(4); 1011-1016.

Chi, L. and R. L. Kushwaha. 1993. A non linear 3-D finite elements analysis of soil forces on curved tillage tools. Canadian Agricultural Engineering. 35: 11-15.

Jun, H., T. kishimoto, R. T. Woy, and T. Taniguch. 1998. Three dimensional contact stress distribution for a pneumatic tractor tyre in soft soil. Trans. of ASAE. 41(5): 1237-1242.

Laughery, S., G. Grant, M. Paul. 2000. Evaluating vehicle mobility using Bekkers equations. US Army TARDEC Warren, MI 48397-5000.

Perdok, U. D. 1978. A predition model for the selection of tyres for towed vehicles on tilled soil. J. of Agril. Engg. Res. 23: 369-383.

Sharma, A. K. and K. P. Pandey. 1997. Effect of normal load on draw bar performance of traction tyres. Journal of Agricultural Engineering. 34(1): 1-9.

Table 3 Average Sinkage at Various Loadings at Soil S_1 and Moisture Content M_2

Sinkage, mm		Applied Load, N		Soil Pressure, N/cm^2	
R_p	C_p	R_p	C_p	R_p	C_p
0	0	0	0	0	0
1.23	1.3	28.78	23.54	0.56	0.29
2.26	2.7	73.26	39.24	1.45	0.48
3.4	4.1	109.89	54.94	2.17	0.68
4.5	5.43	149.13	75.87	2.95	0.94
5.66	6.66	183.15	104.65	3.62	1.30
6.83	7.73	217.16	146.52	4.30	1.82
7.9	8.6	259.02	204.08	5.12	2.54
8.83	9.43	311.35	264.25	6.16	3.29
9.6	10.46	376.76	308.73	7.46	3.85
10.1	11.5	463.10	353.21	9.17	4.40
10.93	12.16	523.28	426.47	10.36	5.32
11.1	12.83	635.79	499.73	12.58	6.23
20.8	13.3	659.7	588.69	13.06	7.34
22.4	14.3	635.79	7.9315.55	663.26	8.28

Table 4 Rolling Resistances of Tractors at Various Soils and at Moisture Content M_1 and M_2

Tractor	Rolling Resistances				
	S_1M_1	S_2M_1	S_2M_2	S_3M_1	S_3M_2
Tr_1	12634	14369	5185	5686	8391
Tr_2	18410	19810	7477	7767	12099
Tr_3	11693	13159	4769	5186	7734
Tr_4	14021	15627	5732	6163	9278
Tr_5	15063	16133	6066	6293	9851
Tr_6	16333	17482	6592	6827	10693
Tr_7	15148	16635	6172	6542	9992
Tr_8	17955	20593	7476	8221	12026

Mechanization of Cassava for Value Addition and Wealth Creation by the Rural Poor of Nigeria

by

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Abstract

In Africa, cassava (Manihot esculenta) is the second most important food staple, after maize, in terms of calories consumed. Cassava is a major source of calories for roughly two out of every five Africans. In some countries, cassava is consumed daily and sometimes more than once a day. Nigeria is among the three largest cassava producing countries in Africa. In 2002, Nigeria recorded an unsatisfactory growth rate of 1.2 %, However, Nigeria's economic performance rebounded, averaging growth at 7.3 % between 2002 and 2007. The pressing challenge for the nation lies in maintaining and improving current economic growth indicators and translating these recent gains into improved standard of living for the majority of its citizens. Poverty within Nigeria remains staggeringly high, averaging 50 % and 70 % of its general and rural population, respectively, living on less than US$ 1.00 a day. Similarly, though Nigeria is often cited as one of the largest oil exporting countries, agriculture still remains the dominant employer of labour of over 70 % and accounting for about 31 % of the nation's Gross Domestic Product (GDP). Cassava is the chief source of dietary food energy for majority of the people living in the lowland tropics, and much of the sub-humid tropics of West and Central Africa. To maintain cassava's competitiveness in world markets, further research is required to increase yields, reduce production costs, broaden the range of starch functional properties and increase the starch content or nutritional value of its root. In addition, processing efficiency needs to be improved, new processes and products developed, and new markets for cassava-based products identified. This can only be achieved by the integration of production, processing and marketing, through active collaboration of the various institutions involved, and through an effective partnership between the public and private sectors. Therefore, its production and utilization must be given prime attention in food policy. This paper aims at presenting an overview of mechanization of cassava in Nigeria and measures to take in promoting its production and processing for value addition and wealth creation.

Introduction

The Nigerian economy is considered the second largest economy in Africa, after South Africa (Africa Research Bulletin, 2006). Despite the fact that oil accounts for 95 % of Nigeria's export earnings and 76 % of government revenues, these have done little for poverty alleviation in the country (Ronchi, 2007). Agriculture still remains a crucial sector, employing over 70 % of the Nigerian labor force and serving as a potential vehicle for diversifying the Nigerian economy for greater economic development.

Cassava is Africa's second most important food staple, after maize, in terms of calories consumed. In the early 1960s, Africa accounted for 42 % of world cassava production. Thirty years later, in the early 1990s, Africa produced half of the world cassava output, primarily because Nigeria and Ghana increased their production four fold. In the process, Nigeria displaced Brazil as the world leading cassava producer. Nigeria is among the three largest cassava producing countries in Africa, together with the Democratic Republic of Congo and Ghana (Nweke, 2004).

Cassava was introduced to some coastal towns of West Africa in the 17th century but it did not spread for almost two centuries because West Africans did not know how to prepare it for consumption (Jones, 1959).

According to United Nations Food and Agriculture Organization (FAO), Nigeria is currently the largest producer of cassava in the world with over 34 million tons produced in 2007. However, most of what is produced is consumed locally, with over 50 % of the harvested produce wasted due to production and post harvest inefficiencies (Ezedinma *et* *al*., 2006).

Cassava (Manihot esculenta) is one of the most important crops grown in Nigeria, playing a dominant role in the rural economy of the southern agro-ecological zones and is increasingly gaining importance in other parts of Nigeria. However, little attention has been given to the cultivation and soil requirement of the crop. This could be attributed to the ease with which the crop grows and because of its position usually as the last crop in the traditional agricultural system before the land is left to fallow (Ande *et al*., 2008).

Cassava is cultivated in virtually all agro-ecology of Nigeria, but good understanding of soil and management is necessary to maintain sustainable production. However, the trend of production shows steady increase of 2.7 % per annum (FAO, 1982), but care must be exercised to maintain a reasonable level of soil fertility and soil structure. Good farming practices and rich/fertile soils using recommended varieties are essential to maintain sustainable production to meet the current high demand for cassava in Nigeria (Ande *et al*., 2008).

In Nigeria, cassava can be processed into different forms of products utilizable by man. IITA (2002) identified and highlighted the characteristics of the common forms of cassava products available in Nigeria. These include gari, fufu, cassava chips, cassava flour, starch, farina, tapioca, macaroni, cassava bread and pudding. A survey conducted by the Federal Ministry of Health revealed that the frequency of consumption of cassava products is high in some states of the country.

High yield in cassava could be attributed to good management practices, use of fertilizer, herbicides and organic manure in some cases, couple with good cultural practices. High yield is also a function of combination of such other factors as appropriate farming systems and cultural practices (Ande *et al*., 2008).

Although reported yield vary considerably ranging from about 4 mt/ha to over 40 mt/ha depending on the cultivar cultural practices, climatic and soil conditions, it is only recently, with the need for more food in several countries and desire to produce higher yield per unit area, that better understanding of the nutritional requirement of the crop is being considered. Cassava is cultivated in all parts of Nigeria, but then, an effective and good understanding of soil and management is necessary to maintain sustainable production (Ande *et al*., 2008).

Stressing the influence of the presidential initiative on cassava in Nigeria, Anga (2005) observed that the trade promotion policy of the federal government has created a very strong domestic demand and market. The demand placed on cassava was so strong that big-time cassava farmers now earn much more money from the produce locally than they could make if they exported the commodity. Ojeagbase (2005) reported that on the international market, a ton of cassava was selling for US$ 120 (about N 15,000). By contrast, the price was US$ 130 (N 16,000) within Nigeria. This gives a difference of $ 10 and without the stress of getting the product ready for export. All the processors of feeds are now finding cassava an effective option for maize and there is a move to replace or partially replace maize with cassava chips. According to Goossens (2004), during the 1980s and 1990s, IITA, CIRAD and CIAT carried out extensive research work on utilization of cassava flour as a partial substitute for wheat in bread (up to 10-15 %), biscuits and snacks (40-100 %). IITA promoted substitution of wheat flour in Nigeria but the impact was limited, because most industries sooner or later had problems with quality and supply of cassava flour. At the moment, constraints are as follows: (a) supply lines for High Quality Cassava Flour (HQCF) are weak; (b) a strong consumer preference for 100 % wheat bread and biscuits; (c) wheat millers are not interested in composite flour, which is technically more complex to use and for which no significant market demand exists; (d) a negative image of cassava flour; some industrial bakeries and biscuit makers had bad experiences (fermentation) with cassava flour in the past. Wheat substitution in bread is in theory a huge potential market with potential to boost industrialization of cassava.

Cassava transformation involves a paradigm shift from production as a low-yielding, famine reserve crop to a high-yielding cash crop, increasingly prepared and consumed as gari. In Nigeria and Ghana, four key factors are driving the cassava transformation. First, the IITA's new high-yielding Tropical Manioc Selection (TMS) varieties boosted cassava yield by 40 % without fertilizer application. Second, high consumer demand for cassava by rural and urban households fueled the producer incentive to devote more land to cassava. Third, the use of the mechanical grater to prepare gari released labor, especially female labor, from processing for planting more cassava. Fourth, the Africa-wide biological control program averted the devastating cassava mealybug epidemic (Nweke, 2004).

Cassava plays different but important roles in African development depending on the stage of the cassava transformation in a particular country: famine reserve, rural food staple, cash crop and urban food staple, industrial raw material, and livestock feed. The first three roles currently account for 95 % of Africa's cassava production while the last two account for only 5 % (Nweke, 2004).

Cassava is a very important food crop that is capable of providing food security. However, a lot of problems prevent the development and use of modern equipment for its production. Most of the cassava

Table 1 Cassava production, area, and yield in the world, the continents and in various countries in Asia in 2004

	Production ('000 tonnes)	Area ('000 ha)	Yield (t/ha)
World	**203,618**	**18,475**	**11.02**
Africa	108,470 (53 %)	12,252	8.85
LAC	34,727 (17 %)	2,696	12.88
Asia	60,245 (30 %)	3,511	17.16
Cambodia	362	23	16.09
China	4,216	251	16.81
India	6,700	240	27.92
Indonesia	19,425	1,255	15.47
Laos	56	8	6.81
Malaysia	430	41	10.49
Myanmar	139	12	11.30
Philippines	1,640	206	7.97
Sri Lanka	221	23	9.54
Thailand	21,440	1,057	20.28
Timor-Leste	42	10	4.15
Vietnam	5,573	384	14.53

Source: FAOSTAT

produced still comes from peasant farmers who depend on manual tools for their field operations and these farmers are instrumental to making Nigeria the world's largest producer of the crop. An increase in production of cassava to sustain the world food security needs improved machinery to allow its continuous cultivation and processing (Kolawole *et al*., 2010).

According to the research findings to enhance the value of cassava as a powerful poverty fighter in Africa poses the following challenges to the African political leaders and policy makers and to cassava researchers and donors (Nweke, 2004):

The resumption of long-term core research funding for cassava research in Africa is critical and urgent.

If any cassava harvesting or peeling machine designed for smallholder farmers can be identified anywhere in the world it should be urgently put to on-farm test in Africa with a view to adapting, fabricating, and diffusing it to farmers if confirmed suitable in the on-farm testing.

If available machines cannot be confirmed suitable for the smallholder farmers use, cassava breeding and engineering research should be initiated with engineers and breeders working hand-in-hand to develop cassava varieties that can be harvested and processed mechanically and the harvesting and the processing machines for the smallholders.

African governments need to encourage their private sectors, for example with intellectual property rights protection, to make the necessary investments in developing technologies for expanded use of cassava as raw material in the livestock feed, food, and non-food industries within Africa.

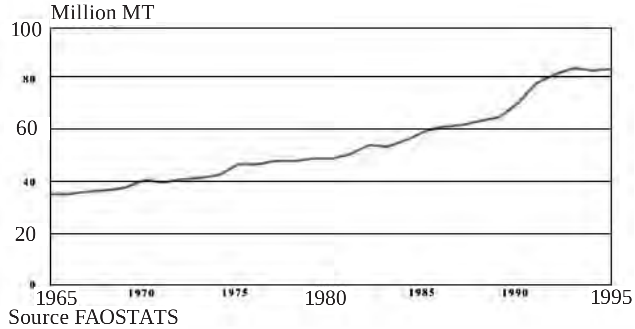
Cassava Production Trends

Cassava has virtually turned to pure gold in Nigeria. Less than five years ago, the country was desperately looking for export market for the farm produce as a result of glut in the local market. But the situation has changed due to the trade promotion policy of the federal government (Ojeagbase, 2005). Nigeria grows more cassava than any other country in the world. The production of cassava is concentrated in the hands of numerous smallholder farmers located primarily in the south and central regions of Nigeria. A significant population of cassava growers in Nigeria has made the transition from traditional production systems to the use of high-yielding varieties and mechanization of processing activities (Nweke *et al*., 2002). **Table 1** indicates that in 2004, about 53 % of cassava in the world was produced in Africa, 30 % in Asia, and only 17 % in Latin America and the Caribbean.

FAO Statistical records taken between the periods of 1965 to 1995 as shown in **Fig. 1** shows the production trend of cassava in sub-Saharan Africa. It can be deduced from **Fig. 1** that the total production of cassava increased from about 35 million tonnes in 1965 to over 80 million tonnes in 1995, an annual growth rate of 2.9 %, which was the same as the population growth rate, an indication that average per capita production has not increased. However, per capita production has increased during the last decade as total production has grown faster (3.8 % than in the preceding decade 2.5 %).

Fig. 2 shows that the five largest producers of cassava in sub-Saharan Africa have increased their share from about 70 to 80 % over the last two decades (FAOSTAT). The big-

Fig. 1 Trend in production of cassava in sub-Saharan Africa, 1965-95



Source FAOSTATS

gest increase has been in Nigeria which increased its share from 22 to 38 % and Ghana which increased its share from 4 to 8 %. The share of other producers has declined and Zaire has moved from being the largest to the second largest producer after Nigeria.

Production Equipment

Mechanization of Cassava Planting

According to Oni and Eneh (2004), cassava is cultivated vegetatively by cutting, although the propagation material is vulnerable to adverse climatic conditions as well as to pests and diseases. Cassava cuttings could be planted upright or at an angle in the soil or horizontally beneath the soil. The orientation of the cutting influences several growth characteristics of the plant. Planting is majorly being carried out manually (i.e. using cutlass to lift the soil and insert the stem to about 10cm unto the soil and cutting off the rest from the buried stem).

Mechanical planters available in the country are not yet fully developed to a level for them to be taken up by fabricators for commercialization. The National Centre for Agricultural Mechanization (NCAM) has in recent times made an in-road into the development of a mechanical planter which is about 75 % completed. The conclusion on planting is that there is yet no commercially available mechanical planter for cassava planting in Nigeria (Oni and Eneh, 2004). **Fig. 3** shows the NCAM-developed prototype cassava stem planter and in operation.

Planting of cassava is usually done on heaps. Herbicide was commonly used for weed control; hence the possibility of residue recycling is high (Ande *et al*., 2008). Oni and Eneh (2004) reported that cassava is susceptible to early weed competition. Slow initial development of sprouts from cassava cuttings makes all cassava cultivars susceptible to weed interference during the first three to four months after planting. The methods of weed control identified are as follows:

Hoe Weeding: This is effective when the farm size is small, and it is the most widely used method in cassava producing areas because the crop is grown mainly by small-scale farmers. Three weeding at 3, 8, and 12 weeks after planting is recommended for maximum output. Hoe weeding may however be preceded by chemical weed control using pre-emergence herbicide (4 litres of Lasso GD mixed with 1 litre of grammozone per hectare and applied using Knapsack sprayer when the soil is moist.

In recent times, NCAM was able to come up with a long-handle hoe which is a better hand hoe than the traditional method being utilized. The long-handle hoe eliminates the bending posture required by the traditional hand hoe method (Johnson, 1982). **Fig. 4** shows the NCAM-developed long Handle hoe in operation.

Biological Weed Control: Biological weed control, known as biocontrol, is a method of controlling undesirable, introduced plants by exposing them to their natural enemies. Biological control attempts to establish a natural balance between the weed and its environment by introducing weed-specific insects or diseases to attack the noxious plants. It also involves the use of in-situ mulch generated by growing a cover crop on stale ridges and seed beds. The goal is not to eliminate the weed but to reduce its population to levels that no longer cause environmental or economic concerns.

Chemical Weed Control: Several herbicides have been identified for weed control for both sole cropping and multiple cropping. Herbicides

Fig. 2 Proportion of cassava produced in selected African countries

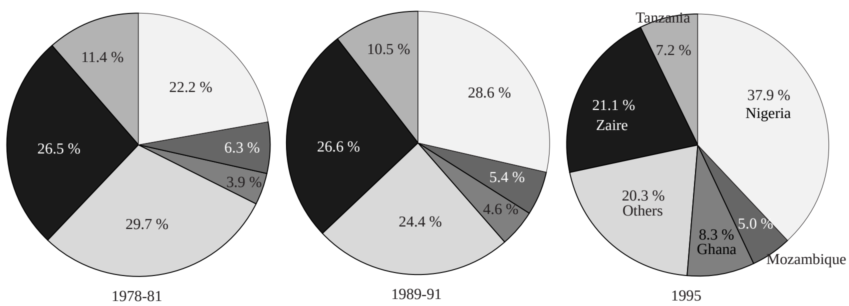


Fig. 3 NCAM-developed prototype cassava stem planter and in operation

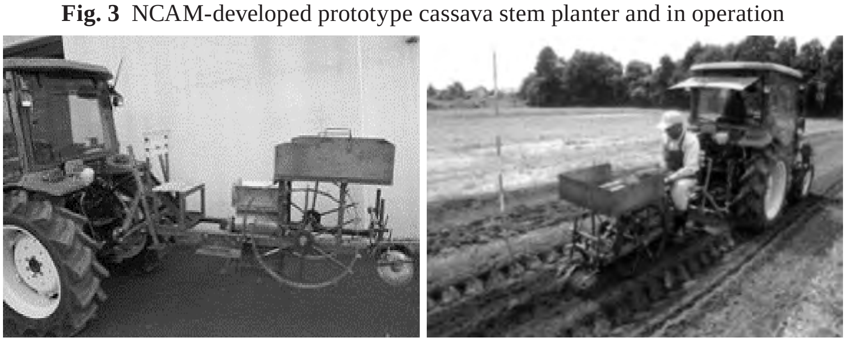


Fig. 4 NCAM-developed long Handle hoe and in operation

that are recommended for pre-emergence weed control in cassava which has been planted from cuttings are chloramben, Diuron, mixture of Lazzo GD with grammozone stated earlier on, etc. Herbicides are most effective if applied to cassava before seedling weeds infest a newly planted field.

Mechanization of Cassava Harvesting

In Nigeria, the harvesting constraint for cassava is reminiscent of the state of grain harvesting in the United States at the beginning of the nineteenth century when grain was still harvested by hand, by the same method that had been used since the fourteenth century (Johnson 2000). Odigboh (1985) reported that in Nigeria, an average manual cassava harvesting rate of about 100 m^2/h has been recorded. Progressive farmers who produce cassava as a cash crop for urban consumption secure labor in two ways. First, they use hired labor for cassava production and harvesting in most of their cassava fields because cassava is grown mostly as a cash crop for urban consumption. However, as wage rates increase in Nigeria, it is becoming difficult for farmers to continue to produce and harvest cassava at prices competitive with grain as harvesting constitutes a major cost factor in cassava production, especially nowadays when agricultural labour is scarce and very expensive.

New mechanical technologies for cassava harvesting and processing are required to generate the rate of growth in cassava production realized in Nigeria from 1987 to 1992. Further improvement in yield-increasing technologies alone will not generate the same level of cassava production growth because genetic technologies which increase yield will only add to the existing labor bottlenecks at the harvesting and processing stages.

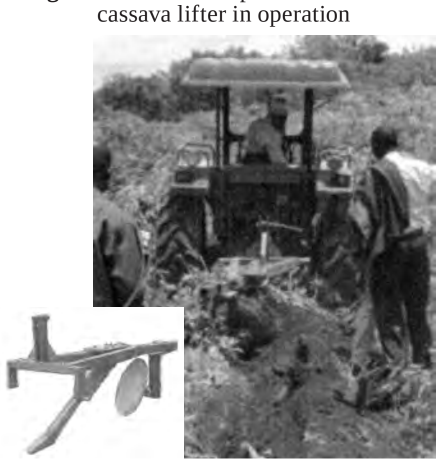
At the National Centre for Agricultural Mechanization (NCAM), a manually operated prototype cassava root tuber lifter has been developed while research is on-going on a tractor mounted prototype tuber harvester that has attained over 80 % harvesting efficiency (Oni and Eneh, 2004). **Figs. 5** and **6** show the harvesting equipment and while in operation, respectively, for both NCAM-developed manual cassava lifter and tractor-drawn cassava lifter.

Processing of Cassava into Gari, Starch, Flour and Ethanol

Kwantia (1986) identified three major classes of cassava processing technologies in Nigeria. These are technologies based on drying and dried products with or without fermentation, and technology based on fermented cassava dough and minor processing technologies. These operations are mainly carried out by women. Karunwi and Ezumah (1988) observed that 84 % of the processors are women and gari is in many cases the major end product.

Fig. 5 NCAM-developed Manual cassava lifter in operation

Fig. 6 NCAM-developed Tractor-drawn cassava lifter in operation



Cassava root processing is mostly done through the use of traditional method which requires that the root be peeled with knife, washed, then followed by the application of different operations to arrive at the desired end-product.

Processing of Cassava into Gari

The traditional way of producing gari requires grating of the peeled cassava tubers after washing. Grating is manually done on a metal grater. The product which is marshy is poured into a sack for the sake of dewatering by putting large stones or wood on top and allowing it to stand for a few days, after which the semi dried mash in the sack is sieved to separate the fibres from the granulated pulp. The granulated pulp is then fried in an open iron cast frying pan to produce gari. These traditional methods have been criticized as grossly inadequate, inefficient, laborious, time-consuming and can only be done on a very small scale (Odigbo, 1979; Ikpi *et al.*, 1986). Report from IITA (1988) showed that power grater can reduce the time needed to grate 140 kg of tubers from 6 hours to 20 minutes. Ikpi *et al.* (1986) maintained that one processing hour on a machine saves women 21 hours' work each week and given the average amount of cassava processed by a household in a year in the Oyo State area surveyed with appropriate cassava processing equipment, each family could save an average of 441 hours of work.

According to Okorji *et al.* (2003), reported in a study carried out in Owerri that gari could be stored up to six months. An average of 18 hours was spent in gari processing using the traditional method. Cassava peeling, sieving and frying took 87 % of the time spent in gari processing using the same traditional method. These processes and stages in the production of gari are the most risky, tasky and labour demanding. The processes and stages in gari production showed that trado-modern method was applied since all the processors used machine and traditional technologies in production. The trado-modern technologies applied during gari making reduced the time of processing separation from an average of 17.52 hours to an average of 11 hours. This is equivalent to 37 % reduction in time of operation in gari production.

Processing of Cassava into Starch

Okorji *et al*. (2003) reported that after grating of the peeled and washed cassava tubers, the pulp produced is sieved using framed fine cloth sieve. Sieving is done in a basin containing water. Care is usually taken by processors not to totally destarch the pulp as they are further processed into gari. The aqueous starch suspension in the basin is allowed to settle and the top water decanted at intervals, starch results after decanting of water. Some processors allow the starch to dry in the container or spread out in a container for sunlight to facilitate its drying. Fifty percent of the processors produced starch during the survey. With the exception of the use of machine grating, the starch production process was traditional. Sixty-six percent of the time spent is used for peeling and sieving during starch production (Okorji *et al*., 2003). An average of nine hours was used in producing starch with cassava tubers. There was the application of trado-modern technique in starch production. The study identified that starch production involved the following stages: cassava tuber peeling, washing, grating, watering and sieving, decanting, stocking filtrate in bag, spreading and sun-drying, (starch). In starch production, the time spent was reduced by 50 % using trado-modern method.

Processing of Cassava into Flour

According to (Agro2), cassava flour is a common feature of Central and South American food, from the Dominican Republic down to Brazil. In these regions it is a popular substitute for wheat flour. It can be used on its own or substituted in products like cookies, cakes and pastries without changing the taste. Cassava flour's texture varies; it can be ground more coarsely to be used in bread or more finely for industrial use in starches or glues. Advantages of cassava flour include: a better flavor; lower cost; and better cooking performance.

In the survey carried out by Okorji *et al*. (2003), 7 % of the processors indicated having processed cassava tuber into flour. The product underwent the following stages: cassava tuber peeling, washing and cutting, soakings, sun-drying, pounding/grinding and then sieving. The soaking in water lasts for about 24 hours after which sun-drying follows. The dried cassava is then ground with mortar and pestle. This lasts for an average of 3.85 hours. The pounded cassava is sieved using framed fine cloth sifter to remove coarse particles thus the fine powdery particles are the cassava flour. Cassava flour can be stored for two months and more than two months during the wet and dry seasons, respectively. The processing of 100 kg cassava tuber into cassava flour took the processors an average of 16 hours which is 66 % of a day. During flour production the time spent was reduced by 13 % using trado-modern method. Trado-modern means combination of modern processing equipment and traditional. These equipment were grater, dewatering, frying and grinding machines.

Processing of Cassava into Ethanol

Ethanol fermentation, also referred to as alcoholic fermentation, is a biological process in which sugars such as glucose, fructose, and sucrose are converted into cellular energy and thereby produce ethanol and carbon dioxide as metabolic waste products. Because yeasts perform this conversion in the absence of oxygen, ethanol fermentation is classified as anaerobic.

Ethanol fermentation occurs in the production of alcoholic beverages and ethanol fuel, and in the rising of bread dough. Ethanol can be made from mineral oil or from sugars or starches. Starches are cheapest. The starchy crop with highest energy content per acre is cassava, which grows in tropical countries. Thailand already had a large cassava industry in the 1990s, for use as cattle feed and as a cheap admixture to wheat flour. Nigeria and Ghana are already establishing cassava-to-ethanol plants. Production of ethanol from cassava is currently economically feasible when crude oil prices are above US$120 per barrel (http:/en.wikipedia.org/wiki/ethanol fermentation).

New varieties of cassava are being developed, so the future situation remains uncertain. Currently, cassava can yield between 25-40 tonnes per hectare with irrigation and fertilizer (Agro 2), and from a tonne of cassava roots, circa 200 liters of ethanol can be produced (assuming cassava with 22 % starch content).

According to (Agro 2), cassava (Manihot esculenta) has the highest energy content of all starchy crops: Up to 300 liters of ethanol per MT. A liter of ethanol contains circa 21.46 MJ of energy (Pimentel, 1980). The overall energy efficiency of cassava-root to ethanol conversion is circa 32 %. The yeast used for processing cassava is Endomycopsis fibuligera, sometimes used together with bacterium Zymomonas mobilis.

Processing Equipment

Small Scale Processing Equipment for Value Addition

Cassava silage as cattle feed and fibrous waste-based broiler feed are value-added products for the feed sector. Industrial products for mini-agri-businesses include wafers, gums and liquid adhesives. Immense scope also exists in biotechnological intervention to produce chemicals, enzymes, eco-friendly detergents, etc. The developmental elasticity of cassava and sweet potato can be enhanced through wider awareness of their potential for starting agri-based units (Padmaja *et al*., 2005).

The International Institute of Tropical Agriculture is currently collaborating Value addition to cassava in Africa with National and International Agencies to promote innovativeness and utilization technologies to add value to cassava in Africa. IITA has recorded laudable achievements in the areas of value adding to cassava varieties, diversified industrial cassava products from flour and starch, and has engaged in the production of flyers, training manuals, books and monographs to stimulate the cassava industry at private level. IITA and other stakeholders are facilitating successful implementation of the policy on 10 % cassava flour in bread from 2005. The policy had stimulated lots of attention and challenges to the cassava sub-sector. IITA is collaborating with National Agencies and Universities in developing glucose syrup from cassava starch (Sanni *et al*., 2005).

As a result of adding value to cassava in Nigeria, the National Centre for Agricultural Mechanization (NCAM) as part of its mandates, has developed an array of cassava processing equipment that local processors could use to produce various cassava end-products at small-scale level. Available at NCAM are, cassava lifter, tractor-drawn cassava harvester, cassava peeling machine, cassava washing machine, cassava grater, cassava chipping machine, combined cassava grater-chipping machine, single and double dewatering press, cassava sifter, cassava sedimentation tank, hammer mill, batch and cabinet dryers and gari fryer.

Gari Processing Equipment

About 10 million tonnes of cassava are processed into gari annually in Nigeria alone (Okafor, 1992). Originally, peeled cassava root was pounded in a mortar with a pestle in the process of making gari. However, artisans later developed a manual grater in the form of a sheet of perforated metal mounted on a flat piece of wood. The efficiency of this hand grater was low because it required high labor input. In the 1930s, the French government introduced mechanical graters in the Republic of Benin and taught farmers how to prepare gari and tapioca for export markets (Jones, 1959). During that same period in Nigeria, local artisans introduced and modified the mechanized grater (Adegboye and Akinwumi, 1990; Adjebeng-Asem, 1990), thus, the gradual spreading of mechanical grater.

In the 1970s, several government Research and Development (R&D) agencies were established in Nigeria to undertake research into the chemical, biochemical, and engineering/processing of crops including cassava. The agencies include the Fabrication Engineering and Production Company (FABRICO), established in 1971; the Products Development Agency (PRODA), established in 1971; the Federal Institute of Industrial Research, Oshodi (FIIRO), established in 1975; the Rural Agro Industrial Development Scheme (RAIDS), established in 1981; and the African Regional Centre for Engineering Designs and Manufacturing (ARCEDEM), established in 1983 (Idachaba, 1998; Idowu, 1998).

Cassava graters developed by government agencies achieved limited adoption because they were more expensive and not as efficient, reliable, or convenient as graters developed by the village artisans. Also, the graters developed by engineers of government agencies have capacities far in excess of the processing needs of the smallholders. As a result, many entrepreneurs who bought the government machines have either had them modified by local artisans or abandoned them (Adegboye and Akinwumi, 1990).

Many artisans and government agencies in Nigeria have invested so much in the development of cassava graters during the period of the Presidential Initiative on Cassava Production and Implementation of the policy on 10 % cassava flour inclusion in bread making which were both introduced by the Obasanjo's administration. Presently in Nigeria, several cassava graters of different designs produced by various fabrication companies and government agencies have flooded the Nigerian market resulting from the government policies of promoting cassava export as revenue earner for the country's economy.

The International Institute of Tropical Agriculture (IITA), Ibadan, at a workshop held in 2006 brought about the collaboration between Nigerian fabricators, engineers from both governmental and non-governmental agencies, and two Brazilian post-harvesting equipment fabricators from Brazil on the development of cassava graters. It was agreed that cassava graters produced in Nigeria needed to be unique and standardized as obtainable in Brazil in order to avoid the problem of non-availability of component parts during repairs.

Apart from the use of cassava graters in producing cassava mash, NCAM has come up with the development of single and double pole dewatering press to replace the traditional method of dewatering cassava mash which involves the use of placing heavy objects on the bagged cassava mash. This traditional means is labour-intensive. Moreso, is not all the water in the cassava mash that could be dewatered when compared with the output of the dewatered cassava mash using the mechanical dewatering press developed by NCAM. The double dewatering press is assisted with the use of a hydraulic jack to quicken the dewatering process of cassava mash. Other gari processing equipment developed by NCAM include NCAM's gari communal fryer made of stainless material for safe consumption of the product.

Starch and Flour Processing Equip-ment

Apart from using the cassava grater and dewatering press for gari processing, so also are the two equipment needed for the production of starch and flour. Drying is an important phase in the production trend of starch and flour processing because the dewatered cassava needs to be dried to its desirable safe moisture content for effective production of products or else the quality of the product will diminish like in the case of cassava flour where the whole processing operation needs to be accomplished within 24 hours or else the processor will record a huge if he/she fails to meet up within the time constraint of 24 hours of operation. Artisans and engineers in Nigeria have developed various types of dryers (batch, cabinet, rotary etc) in a way to meet up the demand of the processing requirement of these two end products. At the National Centre for Agricultural Mechanization (NCAM), several effort have been intensified in this area of producing effective dryers in coming to the aid of our local processors who rely so much on solar energy for drying of the dewatered cassava mash which is labour-intensive and unhygienic for human consumption most especially in the case of cassava flour and chips. The most recent dryer developed at NCAM is the 64-tray cabinet dryer which is incorporated with a burner that can powered using either a diesel or kerosene fuel. Aside this, NCAM have also developed kerosene-fired batch dryer, kerosene-stove fired cabinet dryer, charcoal-fired cabinet dryer etc.

Ethanol Processing Equipment

For ethanol production, a cassava chipping machine is needed. NCAM has developed series of cassava chip machines of various designs which could be manually, thread led and mechanically (motorized) operated.

According to (http://www.cassavabiz.org/postharvest/ethanol01.htm), cassava in its flour form could also be converter to ethanol by passing through the following processing stages: cassava flour, liquification, saccharification, cooling, fermentation, distillation and ethanol. In order to follow this stage of producing ethanol from cassava flour, the following equipment are needed: peeler, grater, jet cooker, fermenter, distiller, steam boiler, generator and efficient treatment plant. Among the listed equipment needed for the production of ethanol from cassava flour NCAM has developed several cassava graters and more so has purchase a cassava peeler from a local fabricator (FATOROY Steel Industry, Ibadan, Oyo State, Nigeria) for adoption. **Fig. 7** shows the pictorial view of the cassava peeling machine adopted by NCAM.

Shelf Life of Cassava Products

Processing of fresh cassava root increases its shelf life, reduces transportation problems and costs, and removes cyanogens. It also improves palatability, adds value, and extends market especially to medium income urban consumers (Nweke *et al.*, 2002). In such large cassava producing countries as Nigeria, the market for processed products is highly limited to low income groups, while other forms of cassava, e.g. gari, a grated precooked fermented cassava product, have a significant market value for middle and high income consumers. How far the market for cassava may be expanded would therefore depend largely on the degree to which the quality of the various processed products can be improved to make them attractive to potential consumers without significant increase in processing costs. Cassava processing is therefore an important factor in marketing because introduction of improved post-harvest handling facilities could lead to a substantial increase in proportion of cassava marketed (Nweke *et al*., 2002).

Improved processing hygiene and packaging could improve their shelf life and make them attractive and acceptable in a wider market. Cassava products processing and utilization is done mainly at the subsistence level (Githunguri, 1995; Kadere, 2002). Most cassava processing technologies are labour-intensive thus facing serious limitations in areas with labour shortages (Mbwika, 2002). Rudimental processing technologies like over reliance on sun-dried methods are rendered impossible during the rainy season. Peeling of cassava roots manually using a knife is time consuming, laborious, difficult to ensure quality control and wasteful. There is need to identify appropri-

Fig. 7 Pictorial view of the old version of FATOROY cassava peeling machine the improved version

ate storage and processing technologies that are cheap, have low losses, improve shelf life and guarantee quality products. Efforts should be made to involve the food processing industry in making ready to eat cassava products available in supermarkets and retail outlets. Due to the enormous potential demand for cassava by the feeds, pharmaceutical, food, paper printing and brewing industries, there is need to involve them in research and development of the cassava sub-sector.

Processing and Effluent Disposal for Environmental Control

Cassava processing is generally considered to contribute significantly to environmental pollution and aesthetic nuisance (Ubalua, 2007). Cassava processing generates solid and liquid residues that are hazardous in the environment (Jyothi *et al*., 2005). There are two important biological wastes derived from cassava processing which are the cassava peels and the liquid squeezed out of the fermented parenchyma mash (Oboh, 2006). The cassava peels derived from its processing are normally discharged as wastes and allowed to rot in the open with a small portion used as animal feed, thus resulting in health and environmental hazards. With hand peeling, the peels can constitute 20-35 % of the total weight of the tuber (Ekundayo, 1980). The wastes generated at present pose a disposal problem and would even be more problematic in the future with increased industrial production of cassava products such as cassava flour and dried cassava fufu. Products of fermentation of cassava peels from such heaps include foul odour and sometimes poisonous and polluted air, which when inhaled by man or animals may result into infection and diseases that may take a long time to manifest. In the same vein, vegetation and soil around the heaps of cassava peels are rendered unproductive and devastated due to biological and chemical reactions taking place between the continuously fermenting peels, soil and the surrounding vegetation. Since these peels could make up to 10 % of the wet weight of the roots, they constitute an important potential resource if properly harnessed biotechnologically (Obadina *et al*., 2006).

In south western part of Nigeria, cassava milling is one of the major industries and the mills are usually sited in places where the effluent is capable of causing pollution on arable lands and fresh water bodies around that are close to the mills. Literature is scanty on the effects of cassava effluents which are usually discharged indiscriminately on the environment, particularly on farmland (Ogboghodo *et al*., 2001). Olorunfemi *et al*. (2007) investigated the effects of cassava processing effluent on the germination of some cereal. The effluent was observed to inhibit the germination of all types of seed used. The percentage germination, length of radicle and plumule of seedlings decreased significantly with increase in effluent concentration. The cassava effluent has been found to increase the number of organisms in the soil ecosystem which may be associated with increase in the soil pH, organic carbon and total nitrogen (Ogboghodo *et al*., 2001). Adejumo and Ola (2001), also studied the effect of cassava effluent on the chemical composition of agricultural soil with the aim of proffering a solution to its indiscriminate disposal and possible benefits on plant growth and discovered in their findings that chemical composition of cassava effluent could serve as a biofertilizer in terms of its potassium and magnesium content. Its use as a biofertilizer will provide an alternative to its wastage, transforming it into an organic supplement for crop cultivation. This will also serve as a compound fertilizer and reduce environmental problems. In conclusion of their findings, they recommended environmental scientists to provide means of extracting the essential elements such as potassium, sodium, etc from cassava effluent for other uses.

Value-Addition of Cassava Waste Products

The dwindling food and feed reserves in the world have increased interest in the exploitation of carbohydrate residues that at present largely go to waste and are pollution hazards. The conversion of organic waste and residues into livestock feed reduces the environmental hazards associated with crop and agro-industrial wastes. The literature is complete with ‘novel’ technologies for treating agricultural waste, including that produced by cassava processing, many involving fermentation by bacteria or yeast for production of biofuel, such as ethanol (Tanticharoen *et al*., 1986; Abraham and Muraleedhara, 1996) or biogas. Other technologies involve the production of single cell protein from cassava waste Pham *et al*. (1992) and Demo-os *et al*. (2000) were able to increase the protein level by 10-20 folds when manufacturing livestock feed with protein-enriched cassava or sweet potato starch solid waste. This could be a potential avenue for processing and adding value to the cassava waste.

Production of animal feed from cassava wastes

This process could contribute to greater use of organic nutrients in waste effluents, thus providing an economical means for minimizing their pollution hazards. The two outer cassava waste materials that constitute the raw materials are; the brown outer peel which consists of lignified cellulosic material and the white inner portion which consists of parenchymatous material and contains most of the toxic cyanogenic glucosides (Okafor *et al*., 1998). It is suggested that they should first be sun-dried to reduce the moisture content to about 10 % or less.

Dried in this manner, they would

be better susceptible to grinding and would also store better. The dried-ground peels are mixed thoroughly with the liquid from the fermenting mash and fermentation is spontaneous. The liquid contains a heavy load of microorganisms capable of hydrolyzing the glucosides (Okafor, 1998). The microorganisms in the fermenting liquid are able to produce linamarase, lysine and amylase. The amylase breaks down any starch granules escaping with the fluid, while the lysine will provide nourishment for the organisms. Fermentation period is for about 48 h, during which a slurry, rich in sugars, lysine and protein derived from the microbial biomass will result. Lysine is usually short in animal feed unless components such as soya bean cake are present. The resulting product can be dried and used as animal feed, whose wastes can be used for biogas production and the effluent and sludge from biogas digester used as fertilizer for the cassava plant, thus providing an integrated system.

Ethanol production from cassava waste

Cassava wastes (residue) obtained during starch processing could be used to produce ethanol (Ubalua, 2007). This could be derived in two ways: enzymatic hydrolysis-which converts cellulosic materials and starch to fermentable sugar and ethanol fermentation which converts fermentable sugar to ethanol by S.cerevisiae TISTR5596 (Teerapatr *et al*., 2004). The production cost of one liter of ethanol using cassava residues as a raw material was 1.5 fold higher than the one from cassava root. However, considering the negative impact of cassava waste and the fact that landfill operation could be decreased up to 81 %, the process is environmentally sound and of immense economic benefit. Thus, utilization of cassava residue for ethanol production could provide the most effective use of natural resources and lead to technology development for further cost reduction (Teerapatr *et al*., 2004).

Waste to worth/wealth

Wastes transformation offers the possibility of creating marketable value-added products. Henry and Howeler (1996), reported that cassava peel can be utilized as a medium for mushroom cultivation or can be used to produce compost. The waste holds moisture and its nutrients are available for growing mushrooms. Already more than 80 % of the cassava solid waste is being used productively, primarily as pig and fish feed and also for other innovative purposes.

Recent Advances in Equipment development in Cassava Processing

Peeling

The major cassava peeling problem arises from the fact that cassava roots exhibit appreciable differences in weight, size and shape. There are also differences in the properties of the cassava peel, which varies in thickness, texture, and strength of adhesion to the root flesh. Thus, it is difficult to design a cassava peeling machine that is capable of efficiently peeling all roots from various sources. Indeed the development of a technically and economically acceptable cassava peeling machine is still a challenge. Many attempts have been made in Nigeria by fabricators and research engineers to come up an efficient cassava peeler that will peel 100 % cassava tuber with a minimal tuber loss of less than 0.5 % which they have not been able to develop to date. But in the recent study carried out by (Kamal and Oyelade, 2010) in knowing the present status of cassava peeling in Nigeria, it was discovered there had been a collaborative effort between IITA, Ibadan; FUTA, Akure; FATAROY, Ibadan; and A & H, Iwo in coming up with a new developed cassava peeling in Nigeria which has already been designed and constructed. The machine is a double action self fed cassava peeling machine which consists of two conveyors arranged in parallel, two rotating and outlets, tuber monitor, a protective hood, frame and transmission system. The machine has the capacity of peeling 1000 kg/h with 10 % and 5 % tuber losses and peel retention, respectively. **Fig. 8** shows the pictorial view of the double action self fed cassava peeling machine.

Drying

Most of the available dryers in Nigeria ranging from batch dryer to cabinet dryers may not meet up with the production-demand level of most of our local processors willing to produce cassava chips and cassava flour in large scale for export because of their low production output rate and low drying rate which has been identified with this series of dryers. In order to arrest this ugly situation, fabricators and engineers in Nigeria have also come up with the emergence of a fast drying technology by adopting flash dryers developed in abroad. In Nigeria today, most agro-processing companies into cassava products have the flash flyers installed in their processing shed for processing of cassava into its final products (starch and flour). Because of the high cost placed on the purchase flash dryers with its cost price ranging between US$ 22150 to US$ 31650, is not all the agro-processing companies in Ni-

Fig. 8 Pictorial view of the double action self fed cassava peeling machine

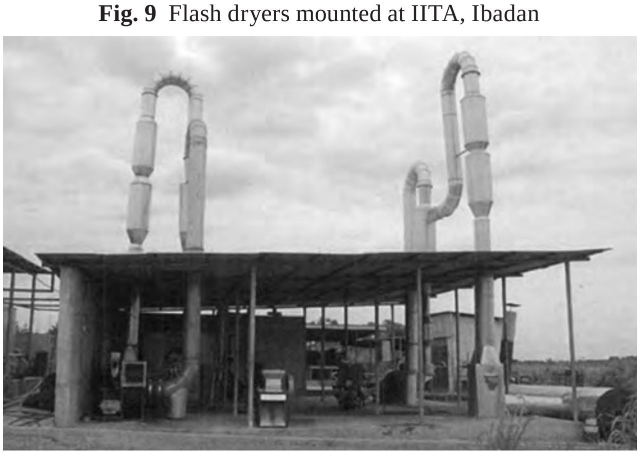
geria that could afford to have one. Research is still on-going in coming up with an effective low-cost mini-flash dryer technology that would be able to function well as those available in the agro-processing companies for use by others processing companies that cannot afford to buy the expensive one. Presently in Nigeria today, top manufacturing companies into flash dryer development are Niji-Lukas Engineering Company, Lagos and Peak Products, Abeokuta. **Fig. 9** shows the pictorial view of the flash dryers developed by Niji-Lukas Engineering Company, Lagos (left-hand-side) and Peaks Products, Abeokuta (right-hand-side) both mounted at the post-harvesting unit of the International Institute of Tropical Agriculture (IITA), Oyo state, Ibadan.

Conclusions and Recommendation

According to United Nations Food Agriculture Organization (FAO), Nigeria stands as the largest producer of cassava in the world. Most of what the cassava produced is consumed locally, with over 50 % of the harvested produce resulting in complete waste due to production and post harvest inefficiencies. This can be attributed to poorly fabricated machines and equipment; farmers lacking skills in processing high grade products; and small and poorly constructed processing units. The development of appropriate production and processing equipment through mechanization of cassava has the potential of making Nigeria attain agricultural development and hence self-sufficiency in food and agro-industrial raw materials. The application of the production and processing equipment is only achievable when they are developed with respect to place of application, user and time of application. Moreso, when they are commercially made available and attainable through research and development.

Presently in Nigeria, there are no technologies potent enough to modernize, energize and revitalize the Nigerian agricultural industry and sufficient to create enabling environment for the emergence of Small-Medium Scale (SMS) market-oriented modern industry which is as a result of our lack of appropriate level of mechanization technologies. Because of the high importance attached to this crop in the international market a lots needs to be done in Nigeria in the area of mechanizing completely the production and processing stage of cassava in order to level up with our competitors in the international markets also gathering the fact wastes derived from cassava (solid and liquid wastes) could be recycled for use as biofertilizer, livestock feeds and mushroom cultivation. This helps in solving the environmental hazard caused by cassava during its processing operation to its various end-products.

Fig. 9 Flash dryers mounted at IITA, Ibadan



Source: Egba (2011)

The manufacturing of production and processing equipment for cassava operation is an important aspect of mechanization development in Nigeria which has not been tackled. This cassava production and processing equipment will give the country the opportunity to compete at the international market with other countries because this cassava production and processing equipment are meant to increase cassava yield through the adoption of proper agronomic practices acquired through training; reduce cost of transportation and minimizing losses during production and processing stage of cassava.

The National Centre for Agricultural Mechanization (NCAM) has the mandate to speed up commercial manufacture but it has to be supported to achieve this goal. The success of the development of production and processing equipment as a strategy for reducing cost of production and processing of cassava depends on the interplay between research institutes, manufacturing industries and other stakeholders (farmers/entrepreneurs). Government serves as the facilitator and a catalyst to enable the three interest groups to function well. It is therefore time (in Nigeria) for medium-scale industries to gradually take over the bulk of processing of root and tuber crops into identified products. It is by so doing that employment can be generated and wealth created for the teeming population of rural Nigeria.

REFERENCES

Abraham, M. and M. Muraleedhara. 1996. Bioconversion of tapioca (Manihot esculenta) waste and water hyacinth (Eichhornia crassipes)-influence of various physico-chemical factors. J. Ferment. Bioeng. 82: 259-263.

Adegboye, R. O. and J. A. Akinwumi. 1990. Cassava processing innovations in Nigeria. In Tinker, tiller and technical change, ed. H.Appleton and N. Carter. New

York, U.S.A.: Intermediate Technology Publications, London and Bootstrap Press.

Adejumo, B. A. and F. A. Ola. 2011. The Effect of Cassava Effluent on the Chemical Composition of Agricultural Soil. Published in the Proceedings of the International Soil Research Organization (ISTRO)-Nigeria Symposium held from 21st-24th February, 2011 at the University of Ilorin, Ilorin, Kwara State.

Adjebeng-Asem, S. 1990. The Nigerian cassava grater. In Tinker, tiller and technical change ed. H. Appleton and N. Cartered. New York, NY, USA: Intermediate Technology Publications, London and Bootstrap Press.

Africa Research Bulletin (ARB). 2006. Nigeria-South Africa: Trade Imbalance: Economic, Financial and Technical Series 43 (10): 17139B-17140C.

Agro2: Ethanol from Cassava.

Ande, O. T., J. A. Adediran, O. T. Ayoola, and T. A. Akinlosotu. 2008. Effects of land quality, management and cropping systems on cassava production in southern western Nigeria. African Journal of Biotechnology, 7(14): 2368-2374. http://www.academicjournals.org/AJB.

Anga, B. 2005. Demand for Cassava Production Equipment up by 500 %. In Success Digest. p.9.

Demo-os, R. A., T. S. J. Valdez, and M. C. Mapili. 2000. Feeding value of protein enriched sweet-potato pulp for broilers. Philipines J. Veteran Anim. Sci., 26: 41-50.

Egba, T. 2011. Commercialization, Prospects and Constraints of Agricultural Machines and Equipment Manufacturing in Nigeria. Lead paper delivered at the 11th International Conference and 32nd Annual General Meeting (AGM) of the Nigerian Institution of Agricultural Engineers held in Ilorin between 17th-20th October, 2011.

Ekundayo, J. A. 1980. In: Fungal Biotechnology. Eds.: Smith, J. E, D. R. Berry, and B. Kristiasen. London: Academic Press. pp. 244 -270.

Ezedinma, C., A. G. O. Dixon, L. Sanni, R. Okechukwu, M. Akoroda, J. Lemehi, F. Ogbe, and Okoro. 2006. Trends in Cassava Production and Commercialization in Nigeria. International Institute of Tropical Agriculture.

FAO. 1982. The state of food and Agriculture, F.A.O. Rome. Food and Agriculture Organization of United Nation, 1979. Production Year Book 1978. Rome, Italy. FAO 32: 116-117.

Githunguri, C. M. 1995. Cassava food processing and utilization in Kenya. In: Cassava food processing. T. A. Egbe, A. Brauman, D. Griffon, and S. Treche (Eds.) CTA, ORSTOM, pp 119-132.

Goossens, F. 2004. Cassava Marketing and Demand Constraints and Opportunities in Nigeria and Ghana. IFAD Report, March 2004.

Henry, G. and R. Howeler. 1996. Cassava in China in an era of change. A CBN case study with farmers and processors. Working Document No. 155. CIAT, Cali, Columbia. p. 18.

http:/en.wikipedia.org/wiki/ethanol fermentation

http://www.cassavabiz.org/postharvest/ethanol01.htm

Idachaba, F. S. 1998. Instability of national agricultural research systems in sub-Saharan Africa: Lessons from Nigeria. Research Report No. 13. The Hague: International Service for National Agricultural Research (ISNAR).

Idowu, I. A. 1998. Private sector participation in agricultural research and technology transfer linkages: Lessons from cassava gari processing technology in Southern Nigeria. In: Postharvest technology and commodity marketing ed. R.S.B. Ferris. Proceedings of a Post-Harvest Conference, November 2-December 1, 1995 in Accra, Ghana and Ibadan, Nigeria: International Institute of Tropical Agriculture.

IITA. 2002. Opportunities for Cassava in Nigeria: Competitiveness Workshop in Bookanga, International Institute of Tropical Agriculture (IITA), Ibadan.

International Institute of Tropical Agriculture, IITA. 1988. Annual Report and Research Highlights 1987/88, Pp. 12-28.

Ikpi, A. E., T. Gebre Meskel, N. D. Halin, H. C. Ezumah, and J. A. Ekpere. 1986. Cassava –a Crop for Household Food Security. A 1986 Situation Analysis of Oyo State Nigeria. IITA-UNICEF Collaborative Program on Promotion of Household Food Production and Nutrition, Socio-economic unit, IITA-Ibadan.

Johnson, D. T. 1982. The Business of Farming, a guide to farm business management in the tropics.

Johnson, D. G. 2000. Population, food, and knowledge. The American Economic Review. 90(1): 1-14.

Jones, W. O. 1959. Manioc in Africa. Food Research Institute, Stanford University, Stanford, U.S.A.

Jyothi, A. N., B. N. Sasikiran, and C. Balagopalan. 2005. Optimization of glutamic acid production from cassava starch factory residues using Brevibacterium divaricatum. Process Biochemistry 40: 3576-3579.

Kadere, T. T. 2002. Marketing opportunities and quality requirements for cassava starch in Kenya. In: Proceedings of regional Workshop on improving the cassava sub-sector, held in Nairobi, Kenya, pp. 81-86.

Kamal, A. R. and O. A. Oyelade. 2010. Present status of Cassava Peeling in Nigeria. Published in the Journal of the Agricultural Engineering and Technology (JAET), 18(2): 7-13.

Karunwi, A. and H. C. Ezumah. 1988. "Economic of Indigenous cassava processing techniques in a Humid Forest Ecology of Nigeria". Cassava based Cropping Systems Research 11, IITA, Ibadan, Pp. 181-193.

Kolawole, P. O., L. Agbetoye, and S. A. Ogunlowo. 2010. Sustaining World Food Security with Improved Cassava Processing Technology: The Nigeria Experience.http://www.mdpi.com/2071-1050/2/12/3681/pdf.

Kwantia, J. J. 1986. Report on the existing cassava storage and processing technologies in Southern Nigeria with a view of making recommendation for the establishment of Rural Cassava Processing and Utilization Centres. UNICEF/IITA Collaborative Program for Household Food Security and Nutrition, October, Ibadan, p. 77.

Mbwika, J. M. 2002. Cassava subsector analysis in the Eastern and Central African region. In: Proceedings of regional Workshop on improving the cassava sub-sector, held in Nairobi, Kenya, April 2002, pp. 8-18.

Nweke, F. I., D. S. C. Spender, and J. K. Lynam. 2002. The Cassava Transformation: Africa's Best Kept Secret. Michigan State University Press, East Lansing, Michigan, U.S.A. 273p.

Nweke, F. I. 2004. New Challenges in the Cassava Transformation in Nigeria and Ghana. Environment and Production Technology Division (EPTD) Discussion Paper No. 118. Publication of the International Food Policy Research Institute (IFPRI), Washington, D.C. U.S.A.

Obadina, A. O., O. B. Oyewole, L. O. Sanni, and S. S. Abiola. 2006. Fungal enrichment of cassava peels proteins. Afri. J. Biotechnol. 5(3): 302-304.

Oboh, G. 2006. Nutrient enrichment of cassava peels using a mixed culture of Saccharomyces cerevisae and Lactobacillus spp solid media fermentation techniques. Electronic Journal of Biotechnology ISSN 0717-3458 by universidad catolica de valparaise.

Odigbo, E. U. 1979. "Mechanical Devices for Peeling Cassava Roots". In small scale processing and storage of Tropical Root Crops, D. L. Plucknett (eds) West view Tropical Agricultural Series No. 1, Pp. 309-324.

Odigboh, E. U. 1985. Mechanization of Cassava Production and Processing: A decade of design and development. University of Nigeria Inaugural Lecture Series No. 8.

Ogboghodo, I. A, I. O. Osenweota, S. O. Eke, and A. E. Iribhogbe. 2001. Effect of cassava (Manihot esculanta Crantz) mill grating effluent on the textual, chemical and biological properties of surrounding soils. World Journal of Biotechnology, 2: 292-301.

Ojeagbase, S. O. 2005. Cassava Turns to Pure Gold. In: Success Digest. May 2005. Pp. 8-10.

Okafor, N. 1992. Commercialization of fermented foods in Sub-Saharan Africa. In Application of Biotechnology to traditional fermented foods. pp. 165-169. National Academy press, U.S.A.

Okafor, N., C. Umeh, and C. Ibenegbu. 1998. Amelioration of gari, a fermented food derived from cassava, Manihot esculenta Crantz, by the inoculation into cassava mash, of microorganisms simultaneously producing amylase, linamarase, and lysine. World J. Microbiol. Biotechnol. In press.

Okorji, E. C., C. C. Eze, and V. C. Eze. 2003. Efficiency of Cassava Processing Technologies among Rural women on Owerri, Imo State, Nigeria.

Olorunfemi, D. I., E. O. Emoefe, and F. E. Okiemen. 2007. Effect of cassava processing effluent on seeding height, biomass and chlorophyll content on some cereals. Department of Botany, University of Benin. Research Journal of Environmental Sciences 2(3): 221-227.

Oni, K. C. and M. C. C. Eneh. 2004. Strategies for Reducing Cost of Production/Processing of Cassava. Paper presented at the facilitation and sensitization workshop for cassava producing States under the Presidential Initiatives on Cassava Production and Export, 8th-12th November, 2004. Federal Ministry of Agriculture and Rural Development, Abuja.

Padmaja, G., S. N. Moorthy, S. K. Nanda, and M. S. Sajeev. 2005. Innovative Approaches in the Value Addition of Sweet potato and cassava for mini agri-businesses in developing Countries. ISHS Acta Horticulture 703: II International Symposium on Sweet potato and Cassava: Innovative Technologies for Commercialization.

Pham, C. B., Lat MRLY, T. J. Ramirez, M. J. Quinlat, and L. J. Pham. 1992. Enriching cassava protein using solid state fermentation. Biotech, University of the Philippines at Los Banos, Philippines.

Pimentel, D. 1980. CRC Handbook of energy utilization in agriculture. (Boca Raton: CRC Press).

Ronchi, L. 2007. Getting Agriculture Going in Nigeria: Statistical Overview of Nigeria's Agricultural Sector. Washington, D.C., World Bank.

Sanni, L., B. Maziya-Dixon, M. Patino, M. Akoroda, C. Ezedinma, R. Okechukwu, J. Lemchi, F. Ogbe, J. Mukumbira, P. Ilona, G. Tarawali, E. Okoro, and A. Dixon. 2005. Value addition to cassava in Africa: Challenges and opportunities. African Crop Science Conference Proceedings, Vol. 7. pp. 583-590.

Tanticharoen M., S. Lerttriluek, and N. Bhumirantana Supajanya. 1986. Biogas production from tapioca wastewater. Proc. Asean Conference on Energy from Biomass. pp. 215-224.

Teerapatr, S., S. Chollada, P. Bongotrat, K. Wichien, and C. Sirintip. 2004. Utilization of waste from cassava starch plant for ethanol production. Joint International Conference on "Sustainable Energy and Environment (SEE)", Hua Hin, Thailand.

A. O. Ubalua. 2007. Cassava wastes: treatment options and value addition alternatives. African Journal of Biotechnology Vol. 6(18): 2065-2073.

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Effect of Exhaust Back Pressure on Noise Characteristic of Tractor Mufflers

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Abstract

Exhaust noise of IC engine is known to be one of the most harmful pollutants to the mankind. However this noise could be reduced sufficiently by means of a well designed muffler. The appropriate design of muffler would able to reduce the noise, but at the same time the performance of the engine is being hampered by the back pressure of exhaust gases which needs to be removed from the engine to breathe it more efficiently. Similarly, from the operator's point of view, emanating sounds from the existing tractors are well above the safe acceptance limit. Thus, a study was taken up to look into effect of back pressure on engine performance and development of a new muffler for reduction in noise and provide comfortable and safer environment to the operator.

Experiment has been carried out with existing muffler and two other selected mufflers of different tractors under varying throttle condition in laboratory. A mercury column U-tube manometer was used to measure exhaust backpressure. Result reveals that backpressure value of existing muffler varying from 0.393 kpa to 4.316 kPa whereas 0.786 kPa -7.06 kPa with other mufflers. It suggested that interchangeability of mufflers to reduce noise level may adversely affect engine performance by increasing back pressure.

The aim of this research is to evaluate the back pressure and afterward validate the theoretical results such as noise level, engine performances, and specific fuel consumptions of the existing and selected mufflers to provide a new design of muffler for better efficiency of man-machine system. The research is being under progress and the presented paper is a part of that research.

Introduction

Technological progress, which aims to gain velocity in production, decreased the physical work burden of men but it has some negative effects on increasing of mental problem while it increases the production in fact. The aim in agricultural mechanization that formed by applications in agricultural production of technology provides an increase in men burden mentally while physical work burden decreases (Celen and Arm, 2003). In this concern, Agricultural equipment manufacturers have directed their efforts toward reducing the sound levels of tractor and self propelled machinery at the operator ear level in recent years. Noise levels of tractors and self propelled agricultural machinery were determined over 90 dBA accepted as danger limit. Although working under 90 dBA for 8 hour is normal, but increment in 2-3 dBA significantly creates hazard for operator ear. Many manufacturers have designed operator workplace for tractors that have noise levels below the safe level of 85 dBA at which hearing loss will not occur after 16 h of exposure. Many operator stations of farm tractors are still characterized by noise levels sufficient to constitute a chronic health hazard (Suggs, 1973).

Today, the modern diesel exhaust system reduces noise and even lends a hand with increasing a vehicle's fuel economy, power and overall derivability. Over the years, the exhaust system has been given more responsibility and its job has grown. Originally, it was a relatively simple duct system designed to prevent toxic exhaust gases from entering the driver's zone. Besides the noise, other bi-products of engine combustion are exhaust particles and gases emitted into the exhaust system. Legislation to control the noise levels and emissions has occurred long time back. Each regulatory change reduced the acceptable levels of combustion-related gases which could be allowed to exit the exhaust system.

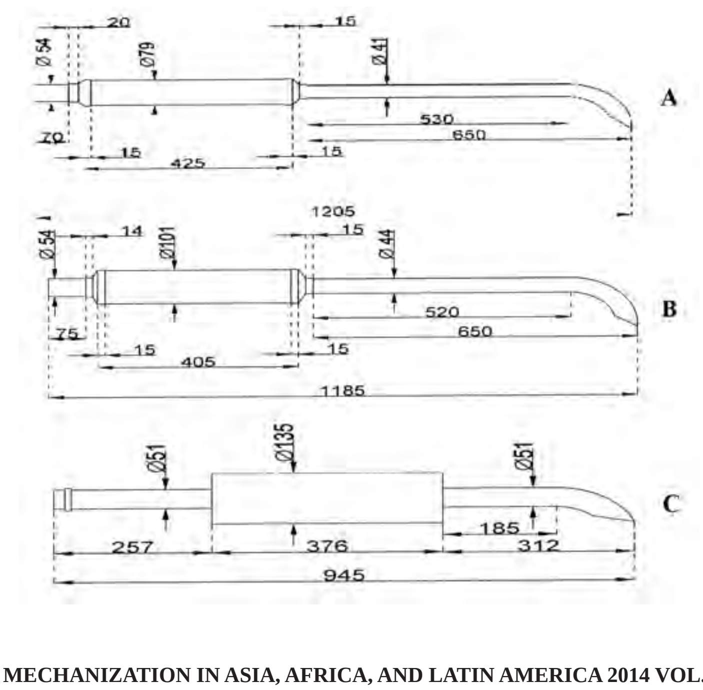
The primary purpose of the exhaust system is to expel burned gases and to dampen the sound of engine combustion. The major parts of exhaust system include manifold, manifold pipe and connector, exhaust pipes and elbows, muffler, tail spout etc. Although the manifold is often thought to be a part of the engine, it is a key component of the exhaust system. The exhaust manifold is the component, usually made of cast iron that gathers all the exhaust as it comes out of the head into a single collector. The manifold then delivers the burned gases into exhaust pipes. The primary purpose of the exhaust pipes is to serve as an enclosed route for the burned gases to exit the system.

The muffler is the primary component within the exhaust system that reduces the noise made by the engine during combustion; as sound waves enter the muffler chamber, they are broken up and the noise dissipates (Bankim *et al*., 2007). Some types of mufflers include chambers with holes, while others are padded with plates to dampen noise levels. The technical challenge is to use a method that most effectively breaks up sound waves without producing excessive back pressure. Some mufflers have efficient design and by using heavier gauge materials with better manufacturing processes could make a noticeable difference in quality, maintenance costs and performance. Bhattacharya *et al*. (2008) stated that there are five different design criterion of mufflers design viz. Acoustical Criterion, Aero dynamical Criterion, Mechanical Criterion, Geometrical Criterion and Economical Criterion. The acoustical criterion which specifies the minimum noise reduction required from the muffler as a function of frequency. Aero dynamical Criterion specifies the maximum acceptable pressure drop through the muffler at given temperature and mass flow. The Mechanical criterion specifies the materials from which the muffler is fabricated or designed. So that it is durable and requires less maintenance. This is especially important in case of involving high temperature exhaust or corrosive gases or the gaseous flow is carrying solid particles in suspension that might be deposited on the inner surface of the wall of the muffler and reduces the muffler effectiveness. Geometrical Criterion specifies the maximum allowable value and restriction on shape while Economical Criterion is vital in the market place. A muffler must be inexpensive as possible while designing initial cost as well as operating cost must be considered.

Exhaust gases are passed through the muffler to reduce the noise of engine combustion. At the same time, back pressure causes exhaust gases to remain in the engine cylinder after the exhaust stroke. While a certain amount of back pressure is vital to optimum performance, too much back pressure can result in loss of horsepower and excessive engine/ turbocharger operating temperatures (Chiu, 2010). When this happens, performance and fuel economy suffer. It may not take much to alter the balance or to affect engine operation. Many mufflers have the same exterior size but vastly different interior construction and performance.

A blockage of exhaust in the engine can cause a back flow of exhaust into the engine, causing the vehicle to be sluggish. Reducing exhaust backpressure can improve fuel economy and performance. Reducing restrictions in the exhaust system allows the exhaust to flow more easily so the engine can breathe more efficiently. A running gas or diesel engine produces a lot of exhaust and heat that needs to be removed from the engine to allow it to run properly (Schwedler *et al*., 2010). Similarly, from the operators point of view, sound pressure emanating from the existing 35 hp tractors are well above the safe acceptance limit. There is a need to develop a muffler to arrest the sound level so that the working environment of the operator is comfortable for more hours of operation.

Fig. 1 Geometrical dimensions of selected muffler



Measuring exhaust backpressure is not as easy as it sounds because there is no quick and easy way to tap into the exhaust system (Anonymous, 2002). To measure exhaust backpressure, there is need to have a pressure gauge with a scale that reads zero to 100 kPa. With this view, a study is taken up to look into effect of exhaust back pressure on engine performance and develop a new muffler for a 35 hp tractor to provide comfort and safety to the operator.

Materials and Methods

Three mufflers have been selected for the study from different horse power range of tractors viz. Muffler A, Muffler B and Muffler C. The dimension and expansion chambers of these three were of different designs and shapes shown in **Fig. 1**. These all mufflers have been tested on specific tractor. The tractor had specification like 29 kW, three cylinders, four stroke, direct injection, water-cooled diesel engine. The Exhaust Back Pressure (EBP) was measured at no load under laboratory condition on tractor by mounting each selected mufflers in which muffler 'C' was originally available with specified tractors.

To measure the EBP, a mercury column U-tube manometer (Hg column) was used that display pressure readings in height (mm) of water column (calibrated). To attach this, a small hole has been drilled into the exhaust pipe at approx. 150 mm from the exhaust manifold and copper tube was used to connect muffler and manometer. The tube was kept in such a way that it could not create any pressure deviation. The exhaust system must be secured to eliminate vibration. One side of manometer was connected to silencer pipe while other end is open in atmospheric pressure. Therefore, the pressure difference between the applied pressure and the reference pressure in a U-tube manometer will be recorded and later on called as EBP. It was make sure that area around clamps has no breakage, cracks and leakage. A leaking muffler represents a potential safety hazard as it may allow exhaust gases to be discharged near the operator's area creating the potential for carbon monoxide to enter the compartment. On vertical exhaust systems, check to ensure that the heat guard around the muffler is secure and in place. **Fig. 2** has shown the experimental view of measuring EBP.

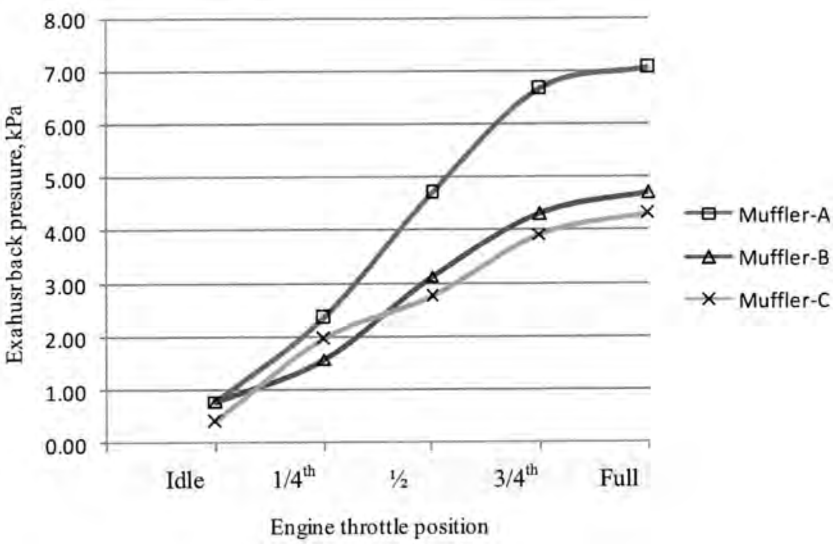
Results and Discussion

EBP may vary somewhat from one vehicle to another depending on the Power, design of the exhaust system, the size of the pipes, how restrictive the converter, muffler and/or resonator is, and whether it is single or dual exhausts. Backpressure readings at idle on most automobile engines should generally be less than 10 kPa. A partially restricted converter or muffler pipe may flow enough exhaust at idle not to cause a problem, but chokes breathing at higher engine speeds. So to test this possibility, we need to rev and hold the engine for instance, at 2000 rpm. A "good" reading on engines at 2000 rpm should be 3 psi (20 to 21 kPa) or less. Again, there may be some vehicles that will read a little higher that don't have a problem, but the reading should not be significantly higher.

Particularly, in case of tractors the EBP have different value compari-

Fig. 2 Measurement of Exhaust Back Pressure (EBP)

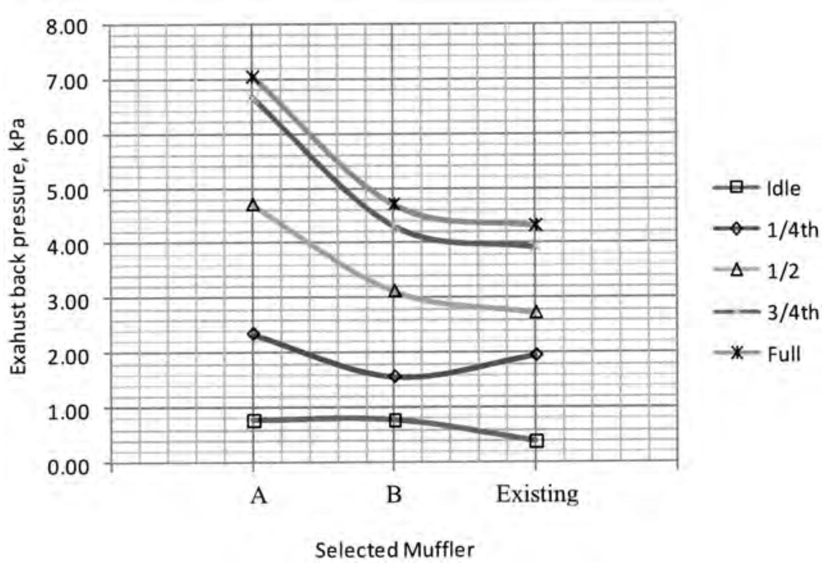
Fig. 3 Effect of engine throttles position on Exhaust Back Pressure (EBP)



son to other automobile vehicle. It was observed that EBP reading was stable at higher throttle position i.e. 3/4th and full which correspond to 2000 and 2500 rpm respectively. So, if it remains steady, chances are there is no restriction. But if the reading gradually increases, it means backpressure is building up and there may be some blockage. If engine rev the maximum rpm and hold it, the backpressure numbers will shoot up. In this situation, Muffler 'A' has shown EBP readings upto 7.06 kPa while the same was 4.71kPa and 4.32 kPa for Muffler 'B' and Muffler 'C' respectively. As before, if the backpressure reading is unusually high or it continues to climb at a steady rpm, it usually means there is an abnormal restriction causing an unhealthy increase in backpressure.

Fig. 3 shows that the EBP on the tractor with different designs of mufflers increased with increase in engine speed at no load under laboratory condition. The EBP increased from 0.79 to 7.06 kPa, 0.79 to 4.71 kPa and 0.39 kPa to 4.32 kPa by increasing the engine throttle position from idle to full of Muffler 'A', Muffler 'B' and Muffler 'C' respectively. The exhaust back pressure levels at rated rpm were 6.68 kPa, 4.32 kPa and 3.92 kPa on tractor under no load condition. The EBP of muffler 'C' was found lowest among tested mufflers. This was due to the expansion area of muffler C which was the highest among the selected mufflers. The effect of backpressure at various engine speeds at not load condition shows in **Fig. 4**. It shows that muffler 'C' has performed with less back pressure compared to others due the higher value of porosity. Obviously, these will increase the engine performance by increasing the volumetric efficiency. There is also an indication that more backpressure could be on the engine at increased load and speed. When mass flow rate is more the backpressure exerted on the engine will be more. Muffler B&C has shown comparatively less backpressure as muffler A. As the volume of the muffler increase, noise attenuation by the muffler will be increase. Muffler C has shown slightly better performance than that of muffler A&B. In muffler A & B, open area ratio was less compare to muffler C. This will increase the backpressure but will improve noise attenuation.

Fig. 4 Comparison of different mufflers at varying engine RPM



Measurement was also carried out to look into the corresponding reading of sound level at operator ear level (OEL) with application of different muffler fitting on particular tractor. It was observed that Muffler C was producing higher noise with least EBP while Muffler B produced low noise (94 dBA) with EBP 4.709kPa. Similarly, Muffler A produced 95 dBA with maximum EBP about 7.06 kPa. It may be revealed that EBP is not only the contributing factor of noise but also interior design of muffler affects the level of noise. It was also found that there was a strong positive relation between noise levels and exhaust back pressure with engine speed. The EBP with Muffler C was the lowest, but there was an increment in noise levels in conversational frequencies at operator's ear level on test track in transportation mode.

Conclusions

It was seen that market muffler was not given noise below the 90 dBA which legislation says. To reduce the noise level, new designing of muffler is essential but reduction may rev the EBP. This investigation suggested that muffler C has been found more efficient than other mufflers in this study. It has shown better characteristics in the sense of acoustic as well as engine performance. The performance of muffler A&B was somewhat inferior to that of muffler C but better result could be obtained after modification. It may be mentioned that muffler C has more volume than muffler A & B. So muffler C could be preferable if space is not a limitation. The design of the mufflers is not much complicated. They can be fabricated by conventional techniques likes welding, machining etc. they are also cost effective.

From the acoustic and engine performance point of view, the recommended mufflers are needed to be tested on other tractors for better substitute. It needs to be mentioned that all the observations and tests have been carried out in the laboratory where the tractor was on a concrete bed. The test results indicate the relative performance of mufflers under the mentioned conditions of experiment. The absolute performance of these mufflers may vary during actual operating condition in an agricultural ground. For instance, the ground may act as a good absorber and isolator and the open ambiance may present a different level of background noise. However the mufflers are expected to show identical relative improvement even in the actual running condition. Noise should be below the 90dBA for 8 hours working exposure with least compromise with EBP. It could be in some limit which cannot be able to reduce engine performance. Reducing exhaust backpressure can improve fuel economy and performance. Reducing restrictions in the exhaust system allows the exhaust to flow more easily so the engine can breathe more efficiently.

REFERENCE

Anonymous. 2002. Development of exhaust muffler and mounting for tractor and power tiller engines. Final project report (3-37/96AE). Indian Council of Agricultural Research, New Delhi. India.

Bankim Bihari Ghosh, Paritosh Bhattacharya, Rajsekhar Panua, and Prabir Kumar Bose. 2007. Prediction of Noise Level by Mathematical Modeling in the Exhaust Muffler and Validation of these Analytical Results with the Experimental Results for 4-Stroke Diesel Engine. Advances in Applied Mathematical Analysis. ISSN 0973-5313 Vol. 2 No. 1, pp. 41-49.

Bhattacharya Paritosh, Panua Rajsekhar, Bose Prabir Kumar, and Ghosh Bankim Bihari. 2008. Design of Reactive Muffler for Study on the Noise Level and Performance of a Two Cylinder Four Stroke 16 H.P Diesel Engine. Noise & Vibration Worldwide. Vol. 39(8): pp 24-27. ISSN 0957-4565.

Celen I. H. and S. Arm. 2003. Noise level of Agricultural Tractors. Pakistan Journal of Biological Science 6(19): 1706-1711. ISSN 1028-8880.

Chiu Min-Chie. 2010. Numerical assessment of reverse-flow mufflers using a Simulated annealing method. Department of Automatic Control Engineering, Chungchou Institute of Technology, Yuanlin, Changhua 51003, R. O. C. No. 08-CSME-45, E. I. C. Accession 3117.

Schwedler David, McQueen Matt, Guan Yun, and Rao Mohan. 2010. Report on Testing and Design of an Integrated Muffler/Catalytic Converter for a Lawn Mower. Michigan Technological University, Houghton, Online access on dated 10/10/2010: www.me.mtu.edu/~yuguan/FinalReport.doc

Sugg, C. W. 1973. Agricultural Machinery Noise and Vibration levels in comparision to human comfort and safety limits. ASAE paper 73-524.

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Optimizing Processing Parameters of Concentric Type Rotary Sieve Grader Using Dimensional Analysis

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Abstract

Using dimensional analysis, various factors influencing the grading efficiency of concentric type rotary sieve grader which was developed for size based grading of in-shell cashewnuts were optimized. The grading efficiency was found to increase as the size of the screen perforations became larger. Optimum length of sieve cylinder observed was 1.2 m for a feed rate of 292 kg h^{-1}, suggesting further increase in screen length would yield negligible increase in the grading efficiency. Residence time of nuts inside sieve cylinder decreased as the slope increased from 9 to 18º and reduced rotational speed (10 rpm) of the sieve cylinder ensured ample opportunity for the nuts to pass through the sieve perforation due to lesser relative motion between the nuts and cylinder. A prediction equation for grading efficiency of rotary sieve grader relating various dimensionless products was developed. About 71.67 % of the predicted values deviated less than ± 10 % from the observed response.

Introduction

The industrial cashew sector is composed of 3750 cashew processing units in India having installed capacity up to 15 lakh MT of in-shell cashewnuts (DCCD, 2011). Around 48.7 % of totally processed in-shell cashewnuts were produced domestically in India and balance quantity imported mainly from African countries. Various unit operations in cashewnut processing are drying, steaming / roasting, shelling, kernel drying, peeling, grading and packaging. Grading of in-shell cashewnuts is the first step in mechanized cashewnut processing followed in many countries for the extraction edible kernels other than India. Moreover, one of the impediments to establish a suitable agency to undertake the collection and marketing of in-shell cashewnut is the absence of standard grading system. While there is an elaborate system of grading for kernels in vogue i.e. 26 grades at international trading level, in-shell cashewnuts are not graded at any level. In the absence of well-defined grading system, producers do not get prices commensurate with the quality of nuts. In-shell nut grading and quality based price structure can encourage the farmers to harvest fully matured nut. A survey on literature reveals that there is no scientific investigation carried out to assess the grading efficiency of mechanical grader exclusively developed for in-shell cashewnuts. In view of the above problems a concentric type rotary sieve grader was developed and this scientific article deals about optimization of various processing parameters related to grading in-shell cashewnuts.

Review of Literature

Dimensional analysis is a mathematical technique to study the dynamics and helps to determine systematic arrangements of variables based on the physical relationships combining dimensional variables to form non-dimensional parameters. Turnquist and Porterfield (1967) established basic relationship between particles and a single screen system using theoretical considerations and dimensional analysis while classifying granular particles in vibratory screeners. A method was also developed for selecting aperture dimensions, screen motions, and area for a screening system having more than one screen to accomplish a given separation. Uichanco and Lantin (1973) studied the effects of diameter of the drum, screen perforation size, length of the exposed screen, angle of inclination of screen, rotational speed and density of input material on output and purity of the cleaning paddy in rotary screen cleaner using dimensional analysis. Dawn (1992) employed dimensional analysis to find out the relationship of various parameters viz., feed rate, diameter of roller, capacity, slope and diameter of the fruit in the design of roller grader for Sapota fruits. It was found that the dimensionless product behaved as a function of effectiveness of separation and showed linear relationship. Datta (2002) optimized various operating parameters viz., operating speed, number of blades and stagger angle ratio which influences the air jet characteristics of axial flow blowers statistically using dimensional analysis. Among the variables selected, dimensionless terms representing discharge coefficient, pressure coefficient, and velocity ratio were opted as dependent pi terms Reynolds number, number of blades and stagger angle ratio as independent pi terms. Senthilkumar (2004) used dimensional analysis to assess the relationship between the machine and operational parameters. Certain pi terms were identified based on the relationship among variables selected. This investigation revealed that the consumption of energy is directly proportional to blade thickness, speed of blade, shear strength of stem and cutting radius and inversely proportional to forward speed and crop density per unit area.

Materials and methods

Optimization of Rotary Grader - Dimensional Analysis

An entirely new approach in the design optimization of rotary screen grader is the use of dimensional analysis. This powerful tool provides a method of combining many variables influencing rotary screen performance in to prediction equation. The basic parameters used to optimize design of rotary screen grader for in-shell cashewnuts are given in the **Table 1**. Due to the large number of independent variables under investigation, the dimensionless groups (Pi terms) were developed (**Table 2**) following Buckingham pi theorem of developing dimensionless products (Langar, 1951).

The general Pi terms related to rotary screen grader is given as,

$$\pi_1 = f(\pi_2, \pi_3, \pi_4, \pi_5, \pi_6) \qquad (1)$$

Qualitative output of the material is the function of above mentioned Pi terms and can be written in the following form

$$\eta = f\,[D/d,\ 1/D,\ N\rho D^3/q,\ 1/N(G/D)^{1/2},\ \theta] \qquad (2)$$

Individual Pi terms and response variable π1 i.e. grading efficiency were related to develop corresponding regression equation to determine optimum values of various parameters considered for the design of rotary sieve grader.

Experiments were scheduled (**Table 3**) considering the functional relationship between response variable, π_1 and various independent variables π_2, π_3, π_4, π_5 and π_6 as follows.–

$$\pi_1 = f(\pi_2, \bar{\pi}_3, \bar{\pi}_4, \bar{\pi}_5, \bar{\pi}_6) \qquad (3)$$

$$\pi_1 = f(\bar{\pi}_2, \pi_3, \bar{\pi}_4, \bar{\pi}_5, \bar{\pi}_6) \qquad (4)$$

$$\pi_1 = f(\bar{\pi}_2, \bar{\pi}_3, \pi_4, \bar{\pi}_5, \bar{\pi}_6) \qquad (5)$$

$$\pi_1 = f(\bar{\pi}_2, \bar{\pi}_3, \bar{\pi}_4, \pi_5, \bar{\pi}_6) \qquad (6)$$

$$\pi_1 = f(\bar{\pi}_2, \bar{\pi}_3, \bar{\pi}_4, \bar{\pi}_5, \pi_6) \qquad (7)$$

Where the bar Pi terms indicate that they were held at pre-determined levels while other terms were varied i.e. one pi term was varied while the others remained constant. The conditions were randomized and replicated three times. Component equations were formulated using the least square method.

Selection of Design Parameter Values

The object of sieving is to completely separate the material based on differences in size. Major factors influencing the degree of sieving are rate of feeding, screen inclination, particle mixture, diameter of screen drum, sieve hole size, length of sieve drum and rotational speed of sieve drum (Uichanco, 1973). Selection of various design parameters and the range of values are given below.

Notations & Symbols used

D	Diameter of Sieve cylinder, m
d	Diameter of sieve hole, m
G	Acceleration due to gravity, m sec^{-2}
L	Length of Sieve cylinder, m
N	Rotational speed of cylinder, rps or
q	Nut input, kg hr^{-1}
θ	Angle of inclination of cylinder, degree
η	Separation efficiency, dimensionless
π_1 to π_6	Pi terms or dimensionless product related to rotary sieve cylinder
Kg	Kilogram
m	metre
rad	radians
rpm	rotation per minute
%	Percentage

Table 1 Basic parameters in rotary sieve grader - Dimensional analysis

Symbol	Parameters	Dimensions
	Geometry	
D	Diameter of Sieve cylinder	L
d	Diameter of sieve hole	L
l	Length of Sieve cylinder	L
θ	Angle of inclination of cylinder	-
	Forces	
q	Nut input	MT^{-1}
N	Rotational speed of cylinder	T^{-1}
g	Acceleration due to gravity	LT^{-2}
	Property o Material	
η	Separation efficiency	-
ρ	Bulk density of in-shell cashewnuts	ML^{-3}

Table 2 Dimensionless products used in rotary sieve grader

Pi term	Description
π_1	η
π_2	D/d
π_3	1/D
π_4	$N\rho D^3/q$
π_5	$1/N(g/D)^{1/2}$
π_6	θ

Diameter of screen cylinder (D)

In view of the number of nuts registering sieve hole per unit time is 17 times which is sufficient enough to grade nuts and considering the cost of construction, the diameter was limited to 65 cm only.

Diameter of sieve hole (d)

Variation curve for the width of the nuts indicated that small (< 20.0 mm), medium (20.1 to 22.0mm) and large (> 22.0 mm) size nuts are in the proportion of 20 : 70 : 10. Therefore sieve sizes of 20 mm φ, 22 mm φ and 24 mm φ were selected.

Length of the sieve cylinder (l)

The standard size of the perforated sheet is 120 × 240 cm. Hence sieve drum length of 120 cm is selected and the experiments were conducted for various lengths viz., 60, 90 and 120 cm. Length was varied by wrapping the screen with thick sheet of 1.4 mm with the exposed screen conforming to the desired length.

Angle of inclination (θ)

Although, experimental results on angle of repose of in-shell cashewnut at safe moisture content indicated value around 28º, preliminary trials on slope of rotary cylinder above 15º resulted very low separation efficiency, therefore the inclination of drum was varied between 6º and 15º at 3º interval.

Feed rate (q) and Acceleration Due to Gravity (g)

Flow of nuts in to the sieve cylinder was kept at the constant level of 150 kg hr^{-1} and acceleration due to gravity was fixed at sea level with a value of 9.81 m sec^{-2}.

Rotational speed (N)

The capacity of the rotary screen grader increases with increasing speed of rotation until a critical speed is achieved. At speeds greater than critical speed, the material does not cascade over the surface but is carried round by centrifugal force and grading is seriously impaired. Critical speed of cylinder with diameter 65 cm is calculated as 27 rpm. In order to promote free movement of nuts along the periphery of the sieve cylinder, rotational speed is restricted below critical speed. Experiments were conducted at 8, 10, 12, 14 and 16 rpm using gear box and pulley assembly.

Density of the input material (ρ)

Performance of the grader also depends on bulk density of input material, therefore the ratio of input material was varied as 1 : 1, 1 : 2, 1 : 3, 2 : 1 and 3 : 1 to give bulk density value of in-shell cashewnuts between 568 to 591 kgm^{-3} to evaluate its performance.

Table 3 Schedule of experiments in optimization of rotary sieve grader for in-shell cashewnuts

π_1	π_2	π_3	π_4	π_5	π_6
	θ	g/DN_2	$q/N\rho D_3$	l/D	d/D
	Angle of inclination, deg	Rotational speed, rps	Bulk density, Kgm^{-3}	Sieve drum length, m	Sieve hole diameter, m
Observed response	6 9 12 15 18	0.13	579.50	1.2	0.022
	6	0.13 0.16 0.20 0.24 0.27	579.50	1.2	0.022
	6	0.13	568.26 572.00 579.50 587.00 591.00	1.2	0.022
	6	0.13	579.50	0.6 0.9 1.2	0.022
	6	0.13	579.50	1.2	0.020 0.022 0.024

Experimental Procedure of Optimizing Rotary Sieve Grader

Determination of basic relationship between particle characteristics, screen parameters and motion of screen would be of practical importance in analyzing and designing rotary screen grading system. Based on the preliminary trial with rotary screen grader, schedule of experiments was formulated (**Table 3**. **6**). Qualitative output of the feed material was calculated from the experimental data and the desired Pi terms were computed.

Eqn. was determined from the relationship between π1 at several values of π_2 by varying the sieve diameter, d. The values of π_3, π_4, π_5 and π_6 were determined by keeping the following parameters constant,

1. Feed rate (q) = 273.61 kg sec^{-1};
2. Cylinder diameter (D) = 0.65 m;
3. Cylinder length (l) =1.20 m;
4. Acceleration due to gravity (g) = 9.81 m sec^{-2};
5. Cylinder slope (θ) = 0.1047 rad;
6. Bulk density of in-shell cashewnut (ρ) = 579.50 Kg m^{-3} and
7. Rotational speed of cylinder (N) = 0.13 rps.

Similarly, equation was framed based on the relationship between π_1 and π_3 at various levels of π_3. Different levels of the required 'pi' term were varied by changing the exposed screen length. All the relevant parameters except length of sieve cylinder were kept at selected level in order to maintain constant values other pi terms considered viz., π_4, π_5 and π_6. Likewise, equations were determined indirectly in a similar manner, but only at several levels of π_4, π_5 and π_6 respectively. Similarly, all the parameters were kept at the same value except those -where the Pi terms were varied. In varying π_4, the density of the input material was varied; in π_3, rotational speed was varied, but the ratio n/q was kept constant and π_6, the angle θ was varied. The equations, thus obtained were analyzed by multiple regression methods. The pertinent parameters were optimized by differentiating component equations and partial differentiation of the general equations. The component equations were combined in an appropriate manner to develop an empirical equation.

Results and Discussions

Effect of D/D Ratio on Grading Efficiency

Relation between grading efficiency and d/D ratio of rotary sieve grader for in-shell cashewnuts is represented in **Fig 1**. Screen roughness index, the ratio between the sieve cylinder diameter and sieve perforation diameter with other factors remaining constant showed increasing trend, indicating increase in number of perforations per unit area. Grading efficiency of the rotary sieve grader increased as the size of the screen perforations i.e d/D ratio became larger. Considering the fact that decrease in perforation size of the screen is accompanied by increase in π_2, structural limitation of the screen could be made accordingly. A decreasing response of roughness index to grading efficiency is observed in vibratory screening system by Turnquist and Potterfield (1967).

Uichanco and Lantin (1973) reported that purity and output decreased as the size of the screen perforations became smaller while optimizing design parameters of rotary screen cleaner for paddy (var. IR-22). Sucher and Pfost (1964) stated that as screen size increase more of the feed material passed through screen in the beginning of the screen along its length, which allowed remaining material more opportunities to strike the screen surface and thus become separated based on the performance evaluation studies on cylindrical grader related to cleaning of Corn.

Effect of L/D Ratio on Grading Efficiency

Optimum length of the screen needed to achieve specified level of response can be determined by the dimensionless ratio (l/D). Grading efficiency was found to increase significantly as the screen length was increased from 0.6 to 1.2 m (**Fig. 2**). Increasing the length within this range increased the chances for the nuts to register with the sieve perforations as it moved from one end of the sieve cylinder to other end. Optimum value of length of the sieve cylinder was computed as 1.2 m for a fixed feed rate of 291.91 kg h^{-1}, suggests that further increase in the length of screen would not result in significant increase in the grading efficiency. Turnquist and Potterfield (1967) considered ratio between length measured from the head end of the screen to the maximum width of the under size particles as screen length index. It is also reported that a positive non-linear relationship existed between these two parameters. This method has been followed to optimize the length of the screen (0.8 m) in rotary screen cleaner to separate paddy grain from chaff material by Uichanco and Lantin (1973).

Effect of 1/N (√G/D) Ratio on Grading Efficiency

Nut movement in the grading area depends on the rotational speed of the sieve cylinder and it influences the grading efficiency. **Fig. 3** is the graphical representation of relationship between grading efficiency and 1/N (√g/D) ratio of rotary sieve grader for in-shell cashewnuts at pre-determined levels of other factors.

Fig. 1 Relationship between grading efficiency (Π_1) and D / d ratio (Π_2) of rotary sieve grader for in-shell cashewnuts

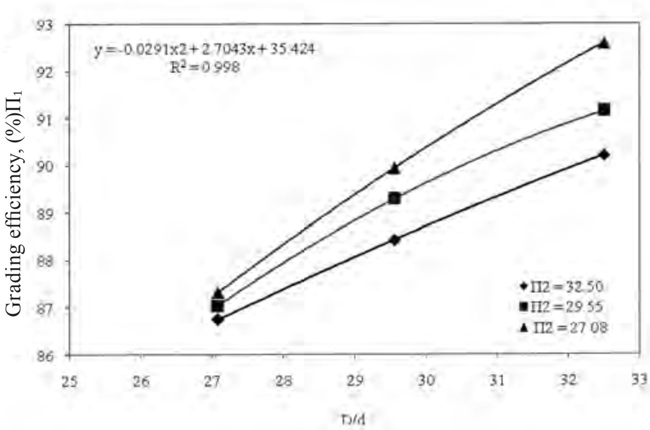
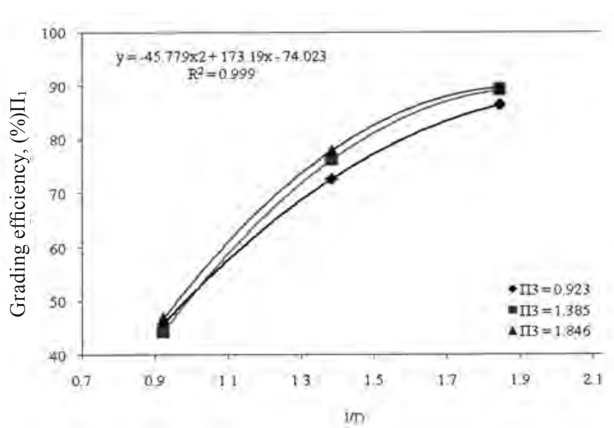


Fig. 2 Relationship between grading efficiency (Π_1) and l/D ratio (Π_3) of rotary sieve grader for in-shell cashewnuts



Increasing trend in the grading efficiency was observed for the decreasing rotational speed of the sieve cylinder. Lesser relative motion (drag effect) between the nuts and the cylinder at lower speeds ensure ample opportunity for nuts to pass through the sieve perforation. This may be the reason for better grading efficiency in size grading of in-shell cashewnuts. Uichanco and Lantin (1973) reported that output decreased as the rotational speed of the cylindrical drum is increased from 12 to 22 rpm for the selected screen size while optimizing rotary screen cleaner for paddy by dimensional analysis method. It is also revealed that shortening the length of exposure of the grains to the screen perforations is a factor resulting decrease of output.

Effect of q/NρD^3 Ratio on Grading Efficiency

Bulk density of in-shell cashewnuts significantly influenced the response variable of sieve cylinder and depicted in **Fig. 4**. Denser the feed mixture, there was lesser the amount of under size nuts in the feed material. As the ratio increases, the oversize nuts are more successful in reducing the number of sieve holes available for under size nuts and tend to convey the under size nuts further down the rotary screen. Similar results are observed by Turnquist and Potterfieldet (1967) while classifying granular particles in a vibratory screen system and for cleaning paddy using the rotary screen principle Uichanco and Lantin (1973).

Effect of Cylinder Angle (Θ) on Grading Efficiency

Relatively higher response between angle of inclination and grading efficiency of rotary screen grader for in-shell cashewnut was observed (**Fig. 5**). Purity of the material obtained at the outlet showed a significant variation in the performance of the grader as the angle of sieve cylinder increased from 0.1 rad (6º) to 0.26 rad (18º). Tendency of the entering nuts gaining higher momentum at higher slope and missing the screen perforations in the upper layer could be the major reasons for the decrease in efficiency when angle of inclination was

Fig. 3 Relationship between grading efficiency (Π_1) and 1/N ($\sqrt{g/D}$) ratio (Π_4) of rotary sieve grader for in-shell cashewnuts

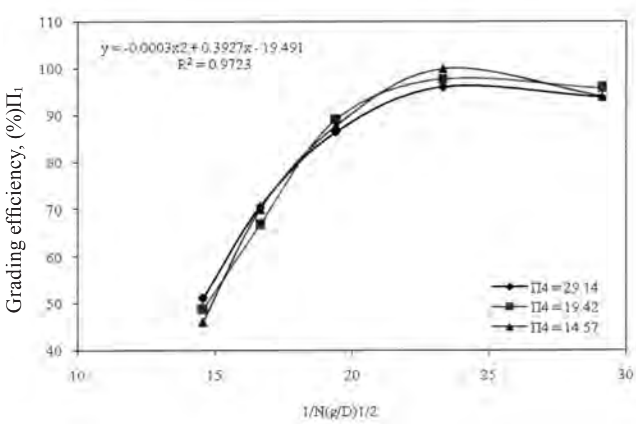


Fig. 4 Relationship between grading efficiency (Π_1) and NρD3/q ratio (Π_5) of rotary sieve grader for in-shell cashewnuts

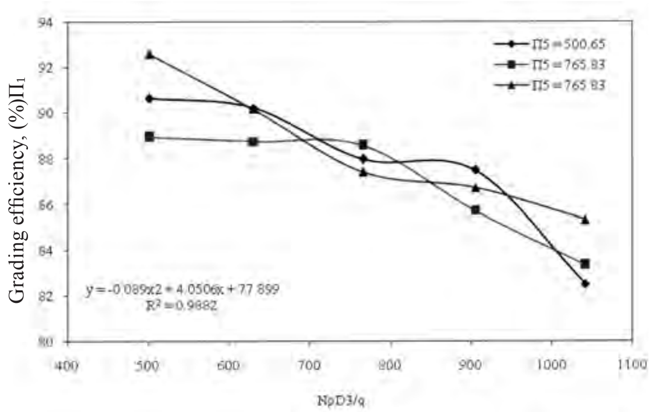


Fig. 5 Relationship between grading efficiency (Π_1) and θ (Π_6) of rotary sieve grader for in-shell cashewnuts

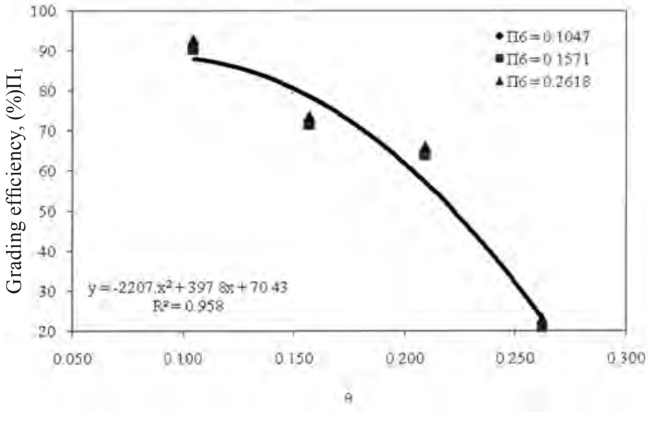
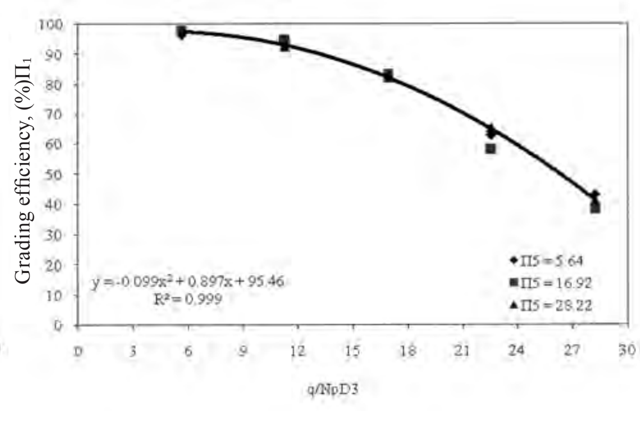


Fig. 6 Relationship between grading efficiency (Π_1) and q (Π_5) of rotary sieve grader for in-shell cashewnuts



increased. Residence time of nuts inside sieve cylinder increased as the slope decreased and it provided greater opportunity for the nuts to register in the sieve holes during its travel from feed to discharge end. Uichanco and Lantin (1973), Turnquist and Potterfieldet (1967) and Sucher and Pfost observed similar trend in the case of rotary screen cleaners for paddy, vibratory screening system for granular particles and cylindrical grader related to cleaning of corn respectively.

Effect of Feed Rate on Grading Efficiency

The effect of feed rate Vs Grading efficiency was determined keeping other independent variables constant by dimensional analysis method. A plot between feed rate and grading efficiency of rotary type sieve grader is shown in **Fig. 6**. Using regression equation the maximum value of feed rate was computed as 119.60 kg h^{-1} for the design parameter selected in rotary type cylindrical sieve separator developed for in-shell cashewnuts. Experimental data revealed that it could be possible to achieve grading efficiency up to 97.58 % using developed rotary grader for in-shell cashewnuts. A statistical program, curve expert 1.3 was used to find out the best fit for the experimental data obtained between feed rate and grading efficiency. A non-linear regression of quadratic form found to be the best fit yielding coefficient determination (R^2) equals to 0.9998.

Similar observations have been recorded by Sucher and Pfost (1964) indicating that increase in feed rate resulted in lower efficiencies under all combinations of cylinder speed and slope while evaluating the performance of cylindrical grader related to cleaning of corn. It is also stated that decreasing efficiency with increasing feed rate results from particle congestion and competition for passage through screen openings.

Development of Component Equation –Models and Coefficients

A prediction equation of the form Y = AX for grading efficiency of rotary sieve grader relating various dimensionless products i.e. $\pi_1 = f(\pi_2, \pi_3, \pi_4, \pi_5, \pi_6)$ was developed following multiple regression technique. Regression equation relating various dimensionless products and grading efficiency developed for single sieve cylinder is presented in **Table 4**. Using these regression **Eqns**, the optimum values of different design parameters were computed and presented in **Tables 4 & 5**. The mathematical model employed to determine various coefficients of the prediction **Eqn.** is as follows.

$$\pi_1 = C_1 \times [\pi_2^2 + C_3\pi_2 + C_4] \times [C_5\pi_3^2 + C_6\pi_3 - C_7] \times [C_8\pi_4^2 + C_9\pi_4 - C_{10}] \times [C_{11}\pi_5^2 + C_{12}\pi_5 + C_{13}] \times [C_{14}\pi_6^2 + C_{15}\pi_6 + C_{16}] \quad (8)$$

The numerical value of corresponding coefficients is presented in **Table 6**. Turnquist and Potterfieldet (1967) and Uichanco and Lantin (1973) followed additive model in the case of vibratory screening system for granular particles and multiplicative models to determine various coefficients and rotary screen cleaners for paddy respectively.

$$\eta = (1/92.161) \times [-0.0291(D/d)^2 + 2.7043(D/d) + 35.424] \times [-45.779\ (1/d)^2 + 173.19\ (1/D) - 74.023] \times [-0.5165\ \{(1/N)\ (g/D)^{1/2}\}^2 + 25.709\ (1/N)\ (g/D)^{1/2} - 217.22] \times [(-3E-05)\ (N\rho D^3/q)^2 + 0.031\ (N\rho D^3/q) + 80.151] \times (-0.1979\ \varphi^2 - 3.35\ \varphi + 116.37) \quad (9)$$

Equation 9 represents the empirical equation to find out the grading efficiency of rotary sieve grader for in-shell cashewnuts incorporating selected parameters influencing its performance. The coefficients of the prediction equation were deter-

Table 6 Coefficients for the prediction equation of rotary sieve grader for in-shell cashewnuts

Coefficient	Numerical value
C_1	92.16048
C_2	−0.02910
C_3	2.70430
C_4	35.4240
C_5	−45.7790
C_6	173.190
C_7	−74.0230
C_8	−0.51650
C_9	25.7090
C_{10}	−217.220
C_{11}	−0.00003
C_{12}	0.03100
C_{13}	80.1510
C_{14}	−0.19790
C_{15}	−3.35000
C_{16}	116.370

Table 5 Optimum values of Π - terms in the design of rotary sieve grader for in-shell cashewnuts

Pi terms	Dimensionless product	Optimum product value		Design parameter	Parameter value
π_2	D/d	30.203	0.021521 D	d, mm	19.63
π_3	l/D	1.892	1.892 D	l, m	1.23
π_4	$(1/N)(g/D)^{1/2}$	24.888	$24.888/(g/D)^{1/2}$	N, rpm	9.37
π_5	$N\rho D^3/q$	516.670	$516.67/ND^3/q$	ρ, kgm^{-3}	335.90
π_6	θ	5.962		θ, deg	8.50

Table 4 Regression equations relating various dimensionless products with grading efficiency (Π 1)

Pi terms	Dimensionless product	Regression equation	R^2
π_2	d/D	−0.0291x 2 + 2.7043x + 35.424	0.999
π_3	l/D	−45.779x 2 + 173.19x − 74.023	0.999
π_4	$(1/n)(g/D)^{1/2}$	−0.5165x 2 + 25.709x − 217.22	0.994
π_5	$n\rho D^3/q$	−3E−05x 2 + 0.031x + 80.151	0.980
π_6	Ø	−0.1979x 2 − 3.35x + 116.37	0.945

mined by the least square method using a total of 60 observations. The comparison of the predicted and the observed values (**Table 7**) indicated that about 71.67 % of the predicted values deviated less than ± 10 per cent from the observed response and 86.67 per cent of the predicted values deviated less than ± 15 per cent.

Conclusions

Dimensionless products were developed using the factors influencing the grading efficiency of single sieve cylinder viz., screen size, length of screen, rotational speed of the sieve cylinder, density of the in-shell cashewnut and angle of inclination of the cylinder following Buckingham pi theorem. The operational parameters of rotary sieve cylinder developed for in-shell cashewnuts were optimized with dimensionless product.

Using dimensional analysis various factors influencing the grading efficiency of cylindrical sieve grader were optimized. Response of grading efficiency of the rotary sieve grader increased as the size of the screen perforations became larger. Optimum length of sieve cylinder was 1.2 m for a fixed feed rate of 291.91 kg h^{-1}, suggesting further increase in the length of screen would not result in significant increase in the grading efficiency. Increasing trend in the grading efficiency at reduced rotational speed of the sieve cylinder was noticed.

The oversize nuts are more successful in reducing the number of sieve holes available for under size nuts and tend to convey the under size nuts along the screen surface towards discharge end, indicating the influence of bulk density on separation efficiency. Purity of the material obtained at the outlet showed a significant variation in the performance of the grader as the angle of sieve cylinder increased from 6º to 18º.

A prediction equation for grading efficiency of rotary sieve grader relating various dimensionless products was developed.

$$\eta = (1/92.161) \times [-0.0291\,(D/d)^2 + 2.7043(D/d) + 35.424] \times [-45.779\,(1/d)^2 + 173.19\,(1/D) - 74.023] \times (-0.5165\,\{(1/N)(g/D)^{1/2}\}^2 + 25.709\,(1/N)(g/D)^{1/2} - 217.22] \times [(-3E-0.5)\,(N\rho D^3/q)^2 + 0.031\,(N\rho D^3/q) + 80.151)] \times (-0.1979\varphi^2 - 3.35\,\varphi + 116.37)$$

About 71.67 % of the predicted values deviated less than ±10 % from the observed response and 86.67 % of the predicted values deviated less than ± 15 %.

Table 7 Comparison of grading efficiency of rotary sieve grader using reduction equation

Observed*	Predicted
92.58	93.22
89.93	90.55
87.32	87.92
46.84	47.16
78.01	78.55
89.68	90.30
93.37	94.02
99.78	99.47
87.28	87.89
67.65	68.11
47.70	48.03
88.15	88.76
87.77	88.38
86.30	86.89
83.63	84.21
79.90	80.45
89.15	89.76
70.19	70.68
47.67	48.00
21.59	21.74

Values indicate average of three replications

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REFERENCE

Datta, A. C., S. K. Das, and A. C. Pandya. 2002. Comparison and optimisation of parameters of axial flow blowers. Journal of Agricultural Engineering. 39(3): 1-11.

Dawn, C. P. A. 1992. Design and development of Sapota grader Unpublished project report. Dept. of Agricultural Processing. Tamilnadu Agricultural University. India.

Langar, H. L. 1951. Dimensional analysis and theory of models. John Wiley and Sons, Inc., New York.

Senthilkumar, T. 2004. Investigation on development of a tractor operated cotton stalk shredder cum in situ application as influenced by crop, machine and operational parameters. Unpublished Ph. D thesis, Tamilnadu Agricultural University, India.

Sucher, R. W. and H. B. Pfost. 1964. Cylindrical grader performance in relation to Corn cleaning problems. Transactions of the American Society of Agricultural Engineers. Paper No.63-801, Chicago. U.S.A.

Turnquist, P. K. and J. G. Porterfield. 1967. Size classifying of granular particles in a vibratory screening system. Transactions of the American Society of Agricultural Engineers. 568-572.

Uichanco, V. A. and R. M. Lantin. 1973. Determination of optimum design parameters of rotary screen cleaners using dimensional analysis. Philipine Agriculturist. 291-308.

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