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EDITORIAL

There is a word widely used at the moment in many organizations or fields such as Japanese industries, universities, research institutions and so on, that is “globalization”. The world certainly is becoming connected and united due to the development of information technology and transport systems. Industries and societies for scientific research are growing more and more difficult to work or serve within a country.

The agricultural machinery industry pursued activities that are mostly dependent on the domestic demand up until recently except for major manufacturers of tractors and other related machines. The demand for agricultural machinery in Japan peaked in 1977 with the value of 700 billion yen and declined to 380 billion yen last year. Leading tractor manufacturers are making steady progress in trying to globalize their business activities. Mid-sized makers for operating machines are subsequently searching for the system to make full use of the technologies developed to the present in a more broad market. Given the prospects for the market for agricultural machinery in the world, I anticipate that the demand will tremendously increase in the 21st century and the agricultural machinery industry will be a growing industry among all other machinery industries. Regarding agricultural mechanization in Japan, the average business scale of farmers or size of working land is particularly small compared to the United States and Europe. Under these circumstances, Japan is a prime country where smaller sized machines are developed the most in the world. When we look around the world, we can find that the average size of farmland is only a few hectares; therefore, the demand for mechanization for the smaller sized machines is extremely high. Of course, it is cheaper to run a huge area of land with large sized machinery, but there are not only large scaled farmers or vast farmlands but millions of small farmers in reality.

There was an international conference on African development (TICAD) in Yokohama city in Japan recently in which the special meeting on the agricultural development was held for a half day. I was invited to be in the conference and delivered a speech on the importance of agricultural mechanization. As I mention over and over again, the world population is growing but the room for farmland to expand is shrinking in the world. In other words we need to increase the crop yields per unit of farmlands in order for humans to live better which means we need to improve land productivity. To pursue this challenge, the most important things we need to consider are timely operation and accurate operation. These can only be achieved by using machinery not by human power. It should be our mission for us all who are engaged in agricultural mechanization to improve land productivity by promoting agricultural mechanization.

There is a tendency to cut down forests to make agricultural lands; however, it is exceedingly dangerous to cut them down anymore considering the ecological balance, improvement of climate conditions and other related issues on the earth. I sincerely wish that a new undertaking should be initiated in order to promote agricultural mechanization in developing countries utilizing technologies and experiences accumulated through the agricultural machinery industries of Japan and other advanced nations. Moreover, it is also important to understand economics of agricultural mechanization. Some say that we should not promote agricultural mechanization because it will only take jobs away from people but this is an absolutely nonsense. If we do not have the correct recognition of economics, investments will not be poured into policies for agricultural mechanization. I deeply hope that agricultural economists will cultivate further understanding of agricultural mechanization and new technologies of machinery.

Yoshisuke Kishida
Chief Editor

July, 2013

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Performance Evaluation of Two Different Seed Cotton Trash Extractors

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Abstract

The aim of the present investigation was to evaluate and compare the performance of two different seed cotton trash extractors namely: local seed cotton trash extractor-cleaner (El-Yamani, 2007) and a foreign extractor (Russian type model YIIX-I, 5T). The performance of the two investigated seed cotton extractors were evaluated in terms of the physical fiber properties included seed cotton fiber length, mm (2.5 and 50 % span fiber lengths); fiber length uniformity ratio, %; color grade, units (color reflectance (Rd) and color yellowness) and seed cotton grade, units. The extractors machine were investigated at four saw drum speeds (7.06, 8.63, 10.20 and 12.56 m.s^{-1}), four feed rates (10, 12.5, 15 and 17.5 kg.min^{-1}) and three fiber moisture contents (11.2, 9.8, 7.9 %). The increase of saw drum speeds, within the range of values included in this study, decreased the 2.5 % and 50 % span fiber length and increased the color reflectance, yellowness and seed cotton grade. At all levels of drum speeds, fiber moisture contents and both extractors, the span fiber length of 2.5 and 50 % and uniformity ratio were proportional to the feed rate. However, the maximum color reflectance, color yellowness and seed cotton grade were achieved at feed rates of 10 kg.min^{-1} at all values of other parameters. The fiber moisture content was highly significant on fiber span length, uniformity, color reflectance and seed cotton grade. However, the fiber moisture content was proportional to fiber span length and uniformity and inversely proportional to color reflectance and seed grade cotton. The highest seed cotton grade was recorded with the locally extractor.

Introduction

The Egyptian cotton still meets a strong demand in the marketplace of manually harvesting of the extra-long staple cotton to achieve a higher grade of seed cotton from the view of containing foreign materials. High cost of manual harvesting will force farmers into mechanical harvesting sooner or later. Seed cotton mechanically harvested contains substantial quantities of trash material such as stems, leaves, hulls and bracts which must be removed in the early stages before ginning. Primary cleaning machines (pre-cleaning extractors) are used for this purpose. The cylinder-type cleaners are generally employed for removal of leaf material and other fine particles, while burs and sticks extractors are employed for the removal of large trash (Garner and Baker, 1977). The cylinder cleaner consists of six or seven revolving spiked cylinders that rotate at 400 to 500 rpm. Centrifugal force created by saw cylinders rotating at 300 to 400 rpm sling off foreign material while the fiber is held by the saw (Anthony, 1990). The modern bur and stick extractor are based on the sling-off principle of trash removal and utilize large-diameter saw cylinders and grid bars to extract trash from seed cotton by a combination of centrifugal and impact forces. While the current systems are normally composed of two extractor –type machines in the seed cotton cleaning system and extractor feeder ahead of the gin stand. These systems are generally 80 to 85 % efficient in removing sticks from seed cotton (Baker and Lalor, 1990). Several attempts have been made to study the effect of deferent operation conditions and cotton varieties on physical properties of fiber. Ahmed *et al*. (1984) found that seed cotton cleaning had highly significant effects on fiber properties. However, the more the cotton was cleaned, the higher percentage of reflectance (Rd %) and micronaire reading were obtained. When further cleaning was applied, lower 2.5 % fiber span length was obtained. Anthony (2000) stated that the less aggressive cotton–type cleaner would cause less fiber damage. Beheary *et al*. (2004) compared between five cotton varieties (Giza 70, 85, 88 and 89) and indicated that the highest mean values of color brightness (Rd %) were recorded by the highest lint grade of the cotton variety Giza 85 and 89 in the first season and the cotton variety Giza 89 in the second season. However, the lowest mean values of the same trait were obtained from the cotton grade (Good) of the cotton variety Giza 89 in both seasons. The grade is a complex idiom for color, trash content, foreign matter and factors related to cotton preparing, equipping and the effects on appearance and quality for resulting cotton. The Egyptian cotton is classifed into seven main grades: Extra (E), Fully Good (F.G.), Good (G), Fully Good Fair (FGF), Fully Fair (FF), Good Fair (GF) and Fair (F). Then it is classified into half grades such as: Extra − ¼, F.F − ¼, FG − ¼, G + ¼, G − ¼ (Baker and Lalor, 1990). Nomeer (1996) found that increases in lint cleaning at the gin tended to improve grade index. The Egyptian cotton varieties are characterized by long-staple and the use of foreign extractors may affect fiber physical properties, therefore, the objective of this study was to evaluate and compare the performance of two different seed cotton extractor machines in the Egyptian cotton.

Table 1 Technical specifications of a new design and Russian extractor machine

Item	Locally extractor (Machine A)	Russian extractor type YIIX-1, 5Y (Machine B)
Length, cm	325	410
Width, cm	135	210
Height, cm	230	252
Weight, kg	1,750	2,400
Source of power	Tractor P.T.O. Shaft.	Tractor P.T.O. Shaft.
Input opening for crop, cm	100 × 30	125 × 33
Out put opening for crop, cm	100 × 30	25 × 50
Diameter of waste conveyer, cm	30	30
Number of impact drams	Four drums	One drums
Diameter of impact drums, cm	30	30
Length of impact drums, cm	100 cm	125
Hole diameter for curved sieve under impact drum	Round holes 10/64⁻	Oblong holes 3/64⁻
Number of saw drum	Three	Three
Diameter of saw drum, cm	30	30
Length of saw drum, cm	100	125
Hole diameter for curved sieve under saw drum, cm	2	1
Diameter of waste auger, cm	20	25

Materials and Methods

Field experiments were conducted at the experimental farm of the El-Karada Research Station (31º05′ N and 30º56′ E) in the Kafr El-Sheikh governorate, Egypt to evaluate and compare the performance of a seed cotton extractor locally designed and foreign extractor (Russian type model YIIX-I, 5T). Giza 86 cotton cultivar was mechanically harvested and used as a rough material for comparing the performance of two extractors. The specifications of the used extractors are presented in **Table 1**. The performance of the two investigated extractors were evaluated in terms of the following fiber physical properties: seed cotton fiber length, mm (2.5 and 50 % span fiber lengths); fiber length uniformity ratio, %; color grade units (color reflectance (Rd) and color yellowness) and seed cotton grade units. The extractor cleaner machines were investigated at four different feed rates (10, 12.5, 15 and 17.5 kg.min^{-1}), four saw drum speeds (7.06, 8.63, 10.20 and 12.56 m.s^{-1} and three fiber moisture contents (11.2, 9.8 and 7.9 %).

Fiber moisture content of the seed cotton was determined at the cotton testing laboratory, Sakha Agricultural Research Station. Three 100 g seed cotton samples of were tested. Other three 750 g seed cotton samples were collected at each experiment and considered for determination of physical fiber properties.

Laboratory Testing:

The Physical fiber properties were determined at fiber testing laboratory, CRI, ARC, Giza. As follows:

Fiber length: The digital fibrograph model 630 used to determine 2.5 and 50 % span fiber length according to May and Bridges (1995).

Uniformity ratio: Determined by using the following formula, where it was expressed on quantity of uniformity between short and long fiber length.

Lint Color: HVI 9000 according to ASTM (1982) (D-1684-96) estimated lint color (reflectance Rd, % and yellowness +b)

Seed cotton grade: Determined by fiber testing laboratory, CRI, ARC, Gaza, by using classified methods. It is done by three cotton classers. The grade was estimated before and after extracting and cleaning.

Statistical procedures: The treatments were laid out in a split-plot in complete randomized design. Data were statistically analyzed by analysis of variance procedures SAS, (1990).

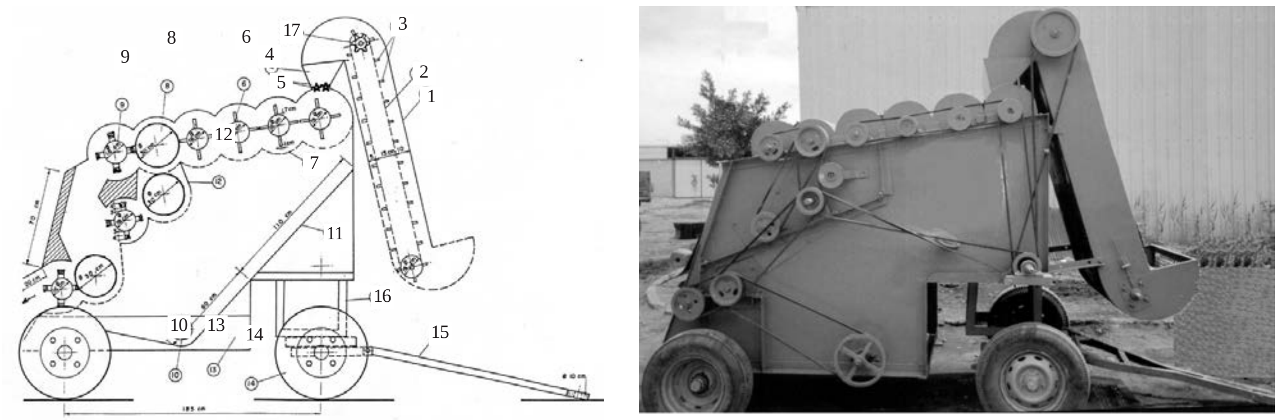
Results and Discussion

Table 2 summarizes the analysis of variance (P value) of the effect of the type of machine, feed rate, fiber moisture content and saw drum speed on fiber physical properties. The physical properties in terms of the tested parameters will be discussed in the following sections.

Seed Cotton Fiber Length:

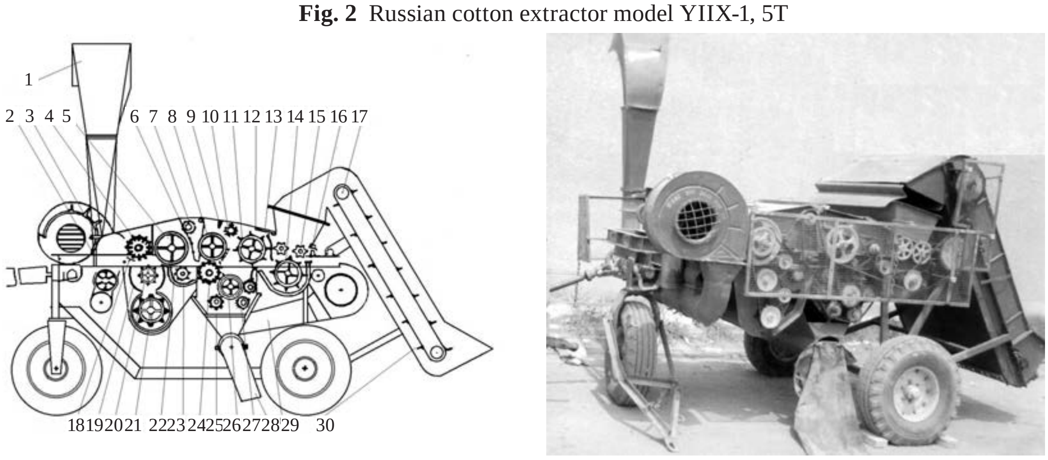
Fiber length determines cotton price in the markets. Fiber length classified as: 2.5 % span fiber length, mm; and 50 % span fiber length, mm. The results indicated that the seed cotton length was significantly affected by the type of extractor, feed rate, fiber moisture content and saw drum speed. **Fig. 3** illustrates the effect of saw drum speeds, feed rates and fiber moisture contents on 2.5 and 50 % span fiber length for both extractor machines. The 2.5 and 50 % fiber length decreased as the saw drum speed increased from 7.06 to 12.56 $m.s^{-1}$ and the fiber moisture content decreased from 11.2 to 7.9 %. Increasing the feed rate from 10 to 17.5 $kg.min^{-1}$ leads to increase 2.5 and 50 % span fiber lengths at all experimental levels. Results observed that the

Fig. 1 Main components of a locally seed cotton extractor machine



1. Mechanical loader, 2. Chain conveyer, 3. Strip, 4. Tank, 5. Feeder roller, 6. Impact drum, 7. Concave, 8. Saw drum, 9. Doffing drum, 10. Trash auger, 11. Division, 12. Inclined surface, 13. Frame body, 14. Wheels, 15. Hitch point, 16. Revolving circle

Fig. 2 Russian cotton extractor model YIIX-1, 5T



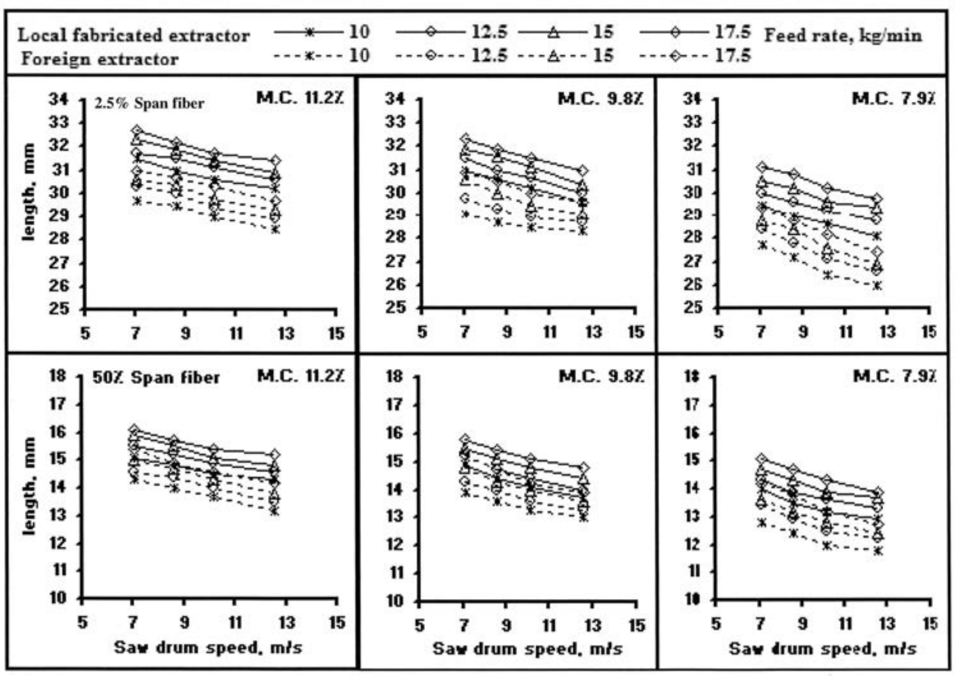
1. Cotton conveyer, 2. Vacuum valve, 3. Fan, 4/24. Doffing drums, 5/8/26. Saw drums, 6/9/18/22. Shielding, 7. Repelling drum, 10. Blade drum, 11. Shelling drum, 12. Shelling concave, 13/19/22. Net, 14. Impurity remover, 15. Feeder roller, 16. Impurity remover net, 17. Mechanical loader, 20, 21. Strip drums, 23. Small sprocket drum, 27. Rubbing drum, 28. Impurity remover hose, 29. Air duct, 30. Collapsible loader section

Table 2 Analysis of Variance (P values) for physical fiber properties

Source	DF	2.5 % span fiber length, mm	50 % span fiber length, mm	Fiber length uniformity ratio, %	Seed cotton color reflectance, unite mean	Seed cotton color yellowness, unite
Machine (M)	1	203.347**	58.500**	12.005**	32.000**	10.657**
Error (a)	4	0.024	0.026	0.034	0.014	0.053
Moisture content (M.C).	2	102.774**	42.467**	40.673**	101.746**	19.110**
M*M.C.	2	1.641**	0.375**	0.370**	0.081**	0.092**
Feed rate (F)	3	28.665**	14.714**	19.483**	30.927**	11.819**
M*F	3	0.017	0.025	0.163**	0.099**	0.120**
M.C.*F	6	0.227**	0.072**	0.041*	0.052**	0.131**
M*M.C.*F	6	0.026	0.012	0.023	0.063**	0.047**
Saw drum speed (S)	3	25.221**	15.974**	27.020**	26.712**	7.887**
M*S	3	0.087*	0.095**	0.390**	0.011	0.154**
M.C.*S	6	0.161**	0.037**	0.177**	0.093**	0.031**
F*S	9	0.045	0.031**	0.019	0.040**	0.017
M*M.C.*S	6	0.315**	0.039**	0.188**	0.141**	0.079**
M*F*S	9	0.058*	0.018	0.021	0.074**	0.008
M.C.*F*S	18	0.043	0.021*	0.023	0.061**	0.038**
M*M.C.*F*S	18	0.034	0.023**	0.037*	0.047**	0.022**
Error (b)	188	0.029	0.011	0.015	0.015	0.009
Corrected Total	187					

high amount of 2.5 and 50 % span fiber lengths recorded with a locally extractor compared to the foreign one. Maximum amount of 2.5 % span and 50 % span fiber length of 32.5 mm and 16.1 mm, respectively, were obtained with a locally extractor at saw drum speed of 7.06 m/s, feed rate of 17.5 kg/min and fiber moisture content of 11.2 %. This improvement could be attributed to minimized stress on seed cotton fiber.

Fig. 3 Effect of saw drum speed on 2.5 and 50 % span length, mm at different feed rates with cotton variety Giza 86 having various moisture contents in cotton fiber for new locally and foreign extractor machines



Fiber Length Uniformity Ratio, %

Results of seed cotton fiber length uniformity ratio as affected by different variables are shown in **Fig. 4**. The effect of fiber length uniformity ratio was highly significant to the type of extractor, feed rate, fiber moisture content and saw drum speed. The uniformity ratio was inversely proportional to feed rate and saw drum speed. It was proportional to fiber moisture content. At all experimental levels, the use of the local extractor led to a higher fiber length uniformity ratio compared with a foreign extractor. Maximum fiber length uniformity ratio of 49.5 % recorded with the local extractor at saw drum speed of 7.06 m/s, feed rate of 17.5 kg/min and fiber moisture content of 11.2 %. That was attributed to increasing the amount of seed cotton fiber length produced by a local extractor.

Seed Cotton Color Grade:

Color grade is one of the important factors determining cotton prices in the international market. It depends on trash content in seed cotton. Color grade classified to seed cotton color reflectance (Rd) and seed cotton color yellowness (+b). Results of seed cotton color reflectance and color yellowness as affected by different variables are shown in **Fig. 5**. Increasing the saw drum speed and decreasing fiber moisture content resulted in a significantly increase in seed cotton color reflectance. While, increasing the feed rate from 10 to 17.5 kg/min led to decrease the seed cotton color reflectance at all operation parameters. The local extractor produced a high amount of color reflectance and low amount of color yellowness compared with a foreign extractor. The highest percentage of color reflectance (Rd) of 73.7 was with the local extractor at a saw drum speed of 12.56 m/s; feed rate of 10 kg/min and fiber moisture content of 7.9 %. The lowest percentage of color yellowness (+b) of 6.2 was achieved at a saw drum speed of 7.06 m/s, feed rate of 17.5 kg/min and 11.2 % fiber moisture content. This could be due to increase the amount of extracted trash and minimize the lint content with a little stress exposed to the seed cotton at these conditions. Thus, this improved the grade and the fiber brightness.

Fig. 4 Effect of type of extractor machine; saw drum speed; feed rate and moisture content of fiber on uniformity ratio, %.

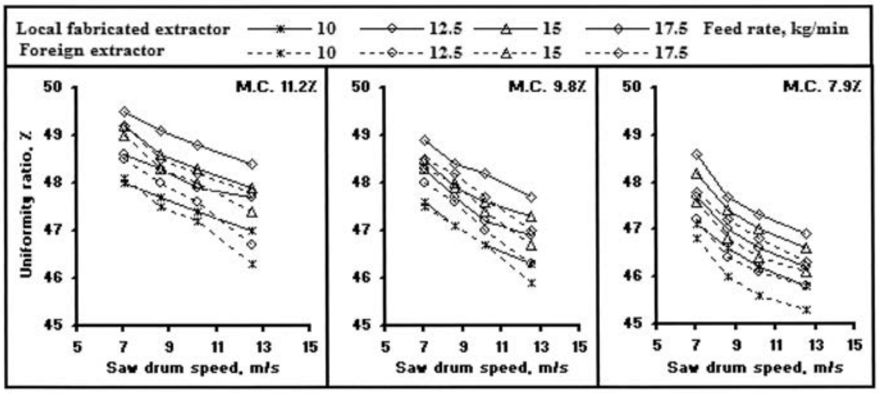
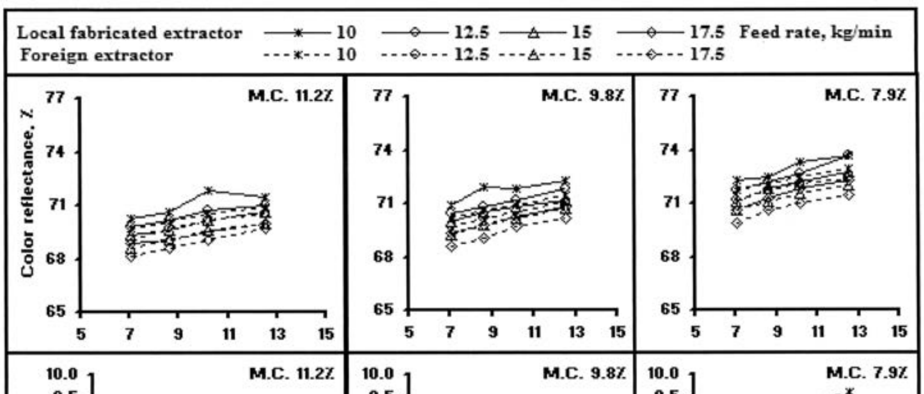


Fig. 5 Main effects of saw drum speed on seed cotton color reflectance and color yellowness at different feed rates with cotton fiber having various moisture contents for both extractor machines.



Seed Cotton Grade, Units:

Table 3 presents the seed cotton grade as affected by different variables, The cotton grade considerably increased as the saw drum speed increased and feed rate decreased. This attributed to increase the amount of trash extracted at highest saw drum speed and lowest feed rate. The seed cotton grade decreased as the cotton moisture content decreased. Also, the results indicated that the local extractor gave a higher degree of cotton grade than the foreign extractor. This may be due to the high efficient of the local extractor in the trash extractor, which improved the cotton grade. The highest cotton grade was recorded at a saw drum speed of 12.58 m/s; feed rate of 10 kg/min and 11.2 % fiber moisture content. At this condition, the amount of extracted trash was higher than the other parameters values.

Conclusion

The main objective of this study was to evaluate and compare the performance of two different seed cotton trash extractors namely: local seed cotton trash extractor-cleaner (El-Yamani) and a foreign extractor (Russian type model YIIX-I, 5T) during cleaning Giza 86 seed cotton variety. Specific conclusions of the study include the following:

1. The increase of the saw drum speed, within the range of values included in this study, was decreased 2.5 % and 50 % span fiber length and increased the color reflectance, yellowness and seed cotton grade.
2. At all levels of drum speeds, fiber moisture content with both extractors, the span fiber length of 2.5 and 50 % and uniformity ratio were proportional to the feed rate. However, the maximum color reflectance, color yellowness and seed cotton grade were achieved at a feed rate of 10 $kg.min^{-1}$ at all values of other parameters.
3. The fiber moisture content was highly significant with fiber span length, uniformity, color reflectance and seed cotton grade. However, the fiber moisture content was proportional to fiber span length and uniformity and inversely proportional to color reflectance and seed grade cotton.
4. The highest seed cotton grade was recorded with the local extractor. From the mentioned results, it can be recommended that the local extractor was considered as the best machine suitable for Egyptian conditions.

Acknowledgements

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REFERENCES

Ahmed, M. S., M. M. Kamal, and M. A. Mahgoub. 1984. Effect of cleaning machinery on trash fiber properties and lint grade of some Egyptian cotton cultivars. Agric. Res. Rev. 62(6): 277-284.

American Society for Testing and Materials ASTM, Standards.

Table 3 Seed cotton grades

Fiber M.C, %	Saw drum Speed, m/s Feed rate, kg/min	Seed cotton grades, unit.					Grade change
		7.06	8.63	10.20	12.56	Control	
Local seed cotton extractor							
11.2	10	G + ¼	G / F.G.	F.G. − ¼	F.G. + ¼	F.G.F.	+
	12.5	G	G + ¼	F.G. − ¼	F.G.	F.G.F.	+
	15	G − ¼	G	G + ¼	G. / F.G.	F.G.F.	+
	17.5	F.G.F. + ¼	F.G.F. / G	G − ¼	G	F.G.F.	+
9.8	10	G	G + ¼	G / F.G.	F.G. − ¼	F.F. / F.G.F.	+
	12.5	G − ¼	G	G + ¼	G. / F.G.	F.F. / F.G.F.	+
	15	F.F.F. − F.G.	F.G.F. / G	G − ¼.	G − ¼	F.F. / F.G.F.	+
	17.5	F.G.F.	F.G.F. + ¼	F.G.F. / G	G − ¼	F.F. / F.G.F.	+
7.9	10	F.G.F	F.G.F. + ¼	F.G.F. / G	G	F.F.	+
	12.5	F.G.F. − ¼	F.G.F.	F.G.F. + ¼	G − ¼	F.F.	+
	15	F.F. + ¼	F.F. / F.G.F	F.G.F. − ¼	F.G.F.	F.F.	+
	17.5	F.F.	F.F. + ¼	F.F. / F.G.F.	F.G.F. − ¼	F.F.	+
Foreign seed cotton extractor							
11.2	10	G	G + ¼	G	G.F.	F.G.F.	+
	12.5	G − ¼	G	G + ¼	G / F.G.	F.G.F.	+
	15	F.G.	G − ¼	G	G + ¼	F.G.F.	+
	17.5	F.G.F. + ¼	F.G.F.	G − ¼	G	F.G.F.	+
9.8	10	G − ¼	G	G + ¼	G / F	F.F. / F	+
	15	F.G.F.	F.G.F.	G − ¼	G	F.F. / F	+
	17.5	F.G.F.	F.G.F.	F.G.	G − ¼	F.F. / F.G.F.	+
7.9	10	F.F. / F.G.	F.G.F.	F.G.F.	F.G.F.	F.F.	+
	12.5	F.F. + ¼	F.F. / F.	F.G.F	F.G.F.	F.F.	+
	15	F.F. − ¼	F.F.	F.F. + ¼	F.F. / F.G.F.	F.F.	+
	17.5	G.F. + ¼	F.F. − ¼	F.F.	F.F. + ¼	F.F.	+

F.G.F. = Fully good fair, G =Good, F.G. = Fully good, E =Extra, F = Fair, G.F.=Good fair, F.F. = Fully fair

1982. Designatians: 64, (684-96). ASTM, Philadelphia , Pa, USA.

Anthony, W. S. 1990. Performance characteristics of cotton ginning machinery. Transactions of the ASAE 33: 1089-1098.

Anthony, W. S. 2000. Methods to reduce lint cleaner waste and damage. Transactions of the ASAE 43: 221-229.

Baker, R. V. and W. F. Lalor. 1990. Multistage trash extractor for cotton gins. Transactions of the ASABE. 33(5): 1457-1463.

Baker, R. V. and W. F. Lalor. 1990. Multistage trash extractor for cotton gins. Transactions of the ASABE. 33(5): 1457-1463.

Beheary, M. G. I., A. E. Hossam El-Din, I. F. Rehab, and H. S. Foda. 2004. Fiber quality index of Egyptian cotton using HVI data. J. Agric. Res. Tanta Univ., 30(4): 830-846.

El-Yamani, A. E. 2007. Manufacturing and performance evaluation of a small machine for cleaning and extracting mechanical harvested seed cotton. Ph. D. thesis, Ag. Eng. Dept., Fac. of Ag., Kafrelsheikh Univ., Egypt.

Garner, W. E. and R. V. Baker. 1977. Cleaning and extracting. Cotton Ginners Handbook, 18-29. Agricultural Handbook No. 503. Agricultural Research Service, U.S. Department of Agriculture. Washington, D.C.

May, O. L. and B. C. Bridges, Jr. 1995. Breeding cottons for conventional and late planted production systems. Crop Science, 35(1): 132-136.

Nomeer, A. A. 1996. Quality control technology in the manufacture of cotton yarn. Arab House for Publishing and Distribution. Cairo, Egypt.

SAS. 1990. SAS User's Guide: Statistics. Ver. 6a. Cary, N.C.: SAS Institute, Inc.

■■

Feasibility of Mechanical Transplanter for Paddy Transplanting in Punjab

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Abstract

Field experiments were conducted at Punjab Agricultural University, Ludhiana during rainy seasons of 2009-2010 to test the feasibility of mechanical transplanters for better establishment, higher yield and profitability in transplanted rice. Three paddy transplanters viz. self propelled walk behind (SWT), self propelled four wheel (SFT) and self propelled single wheel transplanter (SST) were compared with farmer's practice (random transplanting). Results revealed that crop transplanted with SWT gave 9.3 % higher yield than farmer's practice followed by SFT. Increased grain yield with SWT was due to better establishment and more panicles/m^2. Transplanting with SWT also resulted in higher net returns and labour saving. Net returns increased and man-hours/ha saved with SWT to the extent of 14.7 and 87 %, respectively, as compared to farmer's practice.

Looming underground water crisis in Punjab made the government to pass legislation not to transplant paddy crop before 10 June. So, due to the shorter window period for rice transplanting (10-30 June), farmers are facing difficulty in timely paddy transplanting either due to want of labour, or due to high rates being demanded by both migrant as well as local labour. It has been reported that delayed transplanting of paddy during July 5th resulted in reduction in yield (Mahajan *et al.*, 2009 (a)). In Punjab, most of the paddy crop is usually transplanted by migrated labour from Bihar, Orissa, Chhattisgarh and Uttar Pradesh. Arrival of migrant labourers in Punjab has diluted in the past three years due to various reasons. The implementations of infrastructure projects in different parts of the country have provided an alternative employment opportunity to them in their own states. Besides, the central government's National Rural Employment Guarantee Act (NREGA) has also ensured a 100-day employment opportunity. This means they have an option to work in their own land. As a result, earlier, the farmers used to pay Rs. 1750-2000 an hectare to the transplantation labourers, are now offering up to ~Rs. 5,000 an hectare, besides shelter facilities, to ensure timely completion of transplanting. It has been observed that in the past 2-3 years, cost of production in paddy crop has increased and profitability decreased due to rise in wages. In Punjab, payment for transplanting to hired labour is made on area basis rather than number of seedlings transplanted/acre. It has been seen that hired labour completed the transplanting as early as possible and did not maintain the optimum plant density (33 plants /m^2). In most of the cases, they used to transplant ~16 plants/m^2 and caused remarkable reduction in yield. A number of workers have reported that maintenance of critical level of plant density in the rice field was necessary to maximize grain yield (Mahajan *et al.*, 2009 and Shahi *et al.*, 1976). It is, thus, pertinent to evaluate the feasibility of transplanters that may help timely transplanting of the crop and ensure optimum plant population under the face of acute shortage of labourers and a consequent rise in wages.

Materials and Methods

Field experiments were conducted at the research farm of Department of Farm Machinery and Power Engineering, Punjab Agricultural University during Kharif season of 2009 and 2010 to test the performance of different transplanters (self propelled single wheel type self propelled walk behind type SWT and self propelled 4 wheel type) against the current practice, for grain yield differences in rice. Composite soil samples from 0 to 20 cm depth were taken for analyses from each plot prior to start of the experiments. The soil of the experimental sites was loamy sand with 7.2 pH, organic nitrogen 225 mg.kg^{-1}, organic matter 0.28 %, and Olsen P 8.2 mg.kg^{-1}.

Table 1 Brief specifications of the paddy transplanters

Specification	Observations		
Machine	Self propelled single wheel	Self propelled walk behind	Self propelled 4 wheel
Type of nursery used	Mat type	Mat type	Mat type
Power Source	Diesel Engine, 2.94 kW	Petrol Engine, 3.20 kW	Petrol Engine, 12.5 kW
Type of Steering	Mechanical	Handle type	Hydraulic
No. of gear	Forward - 3 (2 for Field & 1 for Road) Reverse - Not Provided	Forward - 1 Reverse - 1	5 Forward & 5 Reverse Speeds
Number of rows	8	4	6
Row to row spacing, cm	23.8	30	30
Plant to plant spacing, cm	14, 17	12, 14, 18, 21	12, 14, 16, 18, 21
Number of hills transplanted/m^2	Two settings	Four settings	Five settings
Transplanting depth	Adjustable	Adjustable	Adjustable
Type of planting finger	Needle type	Plate bar with notch	Plate bar with notch
Material of tray	Galvanized iron sheet	Plastic	Plastic
Type & material of traction wheel	Iron wheel with iron lugs	Iron wheel with rubber lugs	Two front non-puncture rubber wheels & two rear iron wheels with rubber lugs
Transport wheel type	Pneumatic	-do-	-do-
Float type and material	Single piece, fibre	Split bars, plastic	Split bars, plastic

Brief Description of the Machines

A. Self propelled single wheel type paddy transplanter

Self propelled single wheel paddy transplanter is an 8 row riding type machine operated by a 2.94 kW diesel engine. The machine consisted of power a transmission system, handle for operation, main frame and rice transplanting tray, float and transplanting unit. It had a lugged wheel and the weight of the machine rests on the lugged wheel and float at the time of transplanting. The same lugged wheel was replaced by a pneumatic wheel for transportation. Power from the engine is transmitted to front traction wheels through gear train and to the transmission housing of transplanting unit through universal shaft. The machine had 3 forward gears (2 for field and 1 for road). No reverse gear is provided. Row to row spacing is 23.8 cm and plant to plant spacing is adjustable (14 and 17 cm). Two settings are provided for adjusting the number of hills transplanted/sq. meter. Transplanting depth is also adjustable. A view of machine in operation is shown in **Fig. 1** and its brief specifications are given in **Table 1**.

Fig. 1 A view of self propelled single wheel type paddy transplanter in operation

B. Self propelled walk behind type paddy transplanter

Self propelled walk behind type paddy transplanter was a 4 row walk behind type machine operated by a 3.2 kW petrol engine. The machine consisted of power transmission system; handle for steering the machine, main frame and rice transplanting tray, float and two pairs of transplanting units. It had only two lugged wheels and the weight of the machine rests on the lugged wheel and float at the time of transplanting. The same lugged wheels were used for transportation. Power from the engine is transmitted to front traction wheels through gear train and to the transmission housing of transplanting unit through universal shaft. The machine had 1 forward gear 1 reverse gear. Row to row spacing was 30.0 cm and four settings were provided for plant to plant spacing (12, 14, 18 and 21 cm). Four settings were provided for adjusting the number of hills transplanted/sq. meter. Transplanting depth was also adjustable. A view of machine in operation is shown in **Fig. 2** and its brief specifications are given in **Table 1**.

C. Self propelled 4 wheel type paddy transplanter

The self propelled 4 wheel type paddy transplanter was a 6 row riding machine operated by a 12.5 kW petrol engine. The machine consisted of power transmission system; handle for steering the machine, main frame and rice transplanting tray, float and two pairs of transplanting units. It had four lugged

Table 2 Observations, agronomic traits and economics recorded under different treatments

Parameters	Type of paddy transplanter			Farmers' practice (Random transplanting)	LSD (0.05)
	Self propelled single wheel (SST)	Self propelled walk behind (SWT)	Self propelled 4 wheel (SFT)		
Row to Row spacing, cm	23.8	30	30	-	-
Plant to plant spacing, cm	17.0	14	14	-	-
No. of hills/m^2 at machine setting	24.71	23.81	23.81	-	-
No. of hills/m^2 at transplanting	22.18	23.20	22.92	16	-
Missing hills, %	10.24	2.56	3.74	-	-
Mortality, %	11.14	3.35	3.64	-	-
Field capacity, ha/day	1.12-1.3 (1.2)	0.8-1.2 (1)	1.4-4.4 (2.92)	-	-
Plant stand 15 days after transplanting/m^2	19	23	23	15	1.5
Panicles/m^2	276	317	308	278	5.0
Grain yield, kg/ha	7,542.5	8,392.5	8,195.0	7,680	91.7
Cost of production, Rs./ha	22,027	22,515	22,406	23,362	-
Gross return, Rs./ha	77,662	86,438	84,408	79,104	-
Net return, Rs./ha	55,635	63,923	62,002	55,742	-
Man-hours/ha used in transplanting	39	43	39	200	-
Saving in labour cost, %	80	78.4	87.6		-

wheels and the weight of the machine rests on the lugged wheel. The position of therice transplanting tray was adjusted by hydraulic system. The same lugged wheels were used for transportation. The machine had a hydrostatic transmission with 5 forward and 5 reverse speeds. Row to row spacing was 30.0 cm and five settings were provided for plant to plant spacing (12, 14, 16, 18 and 21 cm). Five settings were provided for adjusting the number of hills transplanted/sq. meter. Transplanting depth was also adjustable. A view of machine in operation is shown in **Fig. 3** and its brief specifications are given in **Table 1**.

Evaluation Procedure

Four treatments (farmer's practice and three transplanter treatments as in **Table 2**) were tested in RBD and replicated thrice. Cultivar used for the experimental study was PR-118; a recommended cultivar of PAU. For farmer's practice treatment, a nursery was sown (sprouted seeds were broadcasted in the puddled field, and 30 days old nursery was pulled for transplanting). For transplanter treatments, a mat type nursery was grown. Steel frames having 14 compartments of 40 × 20 × 1.5 cm were used. Number and size of compartment varied according to machine specifications. The crop was transplanted on a puddled field with 25 day old nursery plants in each treatment. Puddling was done by running a cultivator in the standing water (75 mm) followed by planking. In farmer's practice crop, transplanted randomly means no distance between rows and plants was maintained and plant density was maintained 15-16 plants/m^2 as per farmer's practice. Irrigation involved continuous flooding for 15 days after transplanting followed by intermittent irrigation at three

Fig. 2 A view of self propelled walk behind type paddy transplanter in operation

Fig. 3 A view of self propelled 4-wheel type paddy transplanter in operation

day intervals until 14 days before harvest. In the transplanter treatments, depth of water was shallow as compared to farmer's practice during the first 15 days. Weeds were controlled with pre-emergence application of pretilachlor (0.37 kg/ha) applied 3 days after transplanting. A uniform fertilizer dose of 120 kg N/ha through urea was applied to all the plots in three splits, (1/3 as basal + 1/3 at 21 days after transplanting + 1/3 at 42 days after transplanting). The crop was raised under standard package of practices (Anonymous, 2009).

At the harvest of the crop, grain yield of rice was measured at 14 % grain moisture content. For the determination of the agronomic traits, five hills were selected randomly from each plot at crop maturity for recording various parameters including plant height, panicles/m^2, and other crop characteristics. Standard procedures for analysis of variance were used for the statistical analysis of the data collected in the present study (Gomez and Gomez 1984).

Economic Analysis

Human labour uses for tillage, seeding, planting, irrigation, fertilizer and pesticide application, weeding and harvesting were recorded separately for each treatment. Time (h) required to complete operation for each treatment was expressed as person-day/ha (8 h equal 1 person/day). Similarly, time required by tractor to complete tillage (h/ha) and transplanting and time and diesel required for each irrigation (h/ha and l/h, respectively) were also noted. The cost of cultivation was calculated based on the cost of seed, nursery preparation, fertilizer, pesticides, and human labour (Rs. 20/day) and tractor (Rs. 250/h). Gross income was determined on the basis of minimum support price for rice offered by the Government of India. Finally, net income was determined as the difference between gross income and total cost.

Results and Discussion

The crop transplanted with SWT (8.4 t/ha) had highest yield followed by SFT (8.2 t/ha). Crop transplanted with SST gave same yield as that of farmer's practice. Grain yield increased with SWT and SFT by 9.3 and 6.7 %, respectively as compared with farmer's practice. Higher grain yield with SWT and SFT was mainly due to increase in panicles/m^2. Crop transplanted with SST gave same panicles/m^2 as that of farmer's practice. Panicles/m^2 increased by 14 and 10.8 % as compared to farmer's practice. Mahajan *et al.* (2009 b) at the same location reported that in transplanted rice panicles/m^2 had a great influence on grain yield. It was also found that crop establishment was better with SWT and SFT as compared to SST. Mortality was higher (11 %) with SST than SWT (3.3 %) and SFT (3.6 %). Missing hills were also higher in SST (10 %) as compared to SWT (2.6 %) and SFT (3.7 %), respectively. Additional machine cost were Rs. 2666/ha with SST, Rs. 3045 with SWT and Rs. 3153 with SFT. There was huge labour saving found with mechanical transplanters as compared to conventional manual transplanting. For conventional manual transplanting, 200 man hours/ha were used, while with SST, SWT and SFT, 39, 43 and 24 man hours/ha were used, respectively. Roughly, there was 78-88 % labour saving in transplanting with the mechanical transplanter as compared to conventional manual transplanting. Transplanting cost reduced to the extent of 33.3, 23.9 and 21.2 % with SST, SFT and SWT, respectively, as compared to manual transplanting. Highest net return (Rs. 63923/ha) was recorded under transplanting with SWT followed by SFT. Net returns under transplanting with SWT and SFT increased to the extent of 14.7 and 11.2 % compared to farmer's practice.

So, it was concluded that crop transplanted with SWT and SFT not only gave higher yield than manual transplanting, but also resulted more net returns and labour savings. So, in north western part of the Indo-Gangetic Plain, where transplanting was being done through migratory labour that is becoming expansive and scarce, use of mechanical transplanter could be a viable option for rice transplanting.

REFERENCES

Anonymous. 2009. Package of practices for kharif crops. Punjab Agricultural University, Publication

Gomez, K. A. and A. A. Gomez. 1984. Statistical Procedures for Agricultural Research. Wiley- Inter science Publication, John Wiley and Sons, New York. Pp 680.

Mahajan, G., T. S. Bharaj, and J. Timsina. 2009(a). Yield and water productivity of rice as affected by time of transplanting in Punjab, India. Agricultural Water Management 96: 525-35.

Mahajan, G., N. Singh, and R. Kaur. 2009(b). Optimization of transplanting time, nitrogen requirement and plant spacing for higher yield of basmati rice cultivars in Punjab. Environment and Ecology 28: 770-74.

Shahi, H. N., P. S. Gill, and Khind C. S. 1976. Effect of number of seedlings per hill and spacings on growth and yield of rice. Indian Journal of Agronomy 21: 392-395.

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Modification and Performance Evaluation of a Reciprocating Machine for Shelling Peanut

by

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Abstract

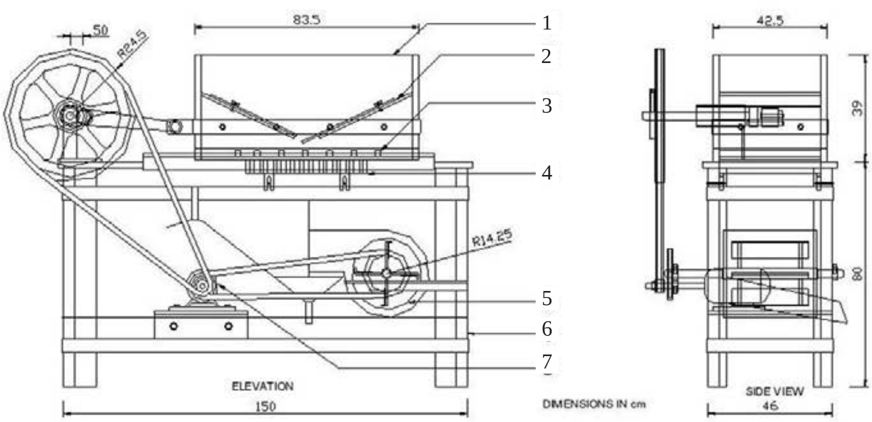
A reciprocating peanut sheller was fabricated as a multi-crop sheller to shell peanut, soybean, bean, etc. (Helmy, 2001). It was constructed at the Agricultural Engineering Workshop, Faculty of Agriculture, Kafr Elsheikh Governorate and modified at the workshop of Rice Mechanization Center, Meet Eldeeba, Kafr Elsheikh Governorate, Egypt throughout the year of 2006. The present study was mainly carried out to evaluate the performance of a reciprocating peanut sheller before and after modification by supplying the sheller with feeding mechanism (conveyor belt), increasing the friction area of shelling box, and using rubber for enhancing shelling process. The experimental results showed that, the performance of a reciprocating peanut sheller after modification is better than, that before modification. Where, the value of shelling efficiency after modification was of 98.85 %, damaged seeds of 1.36 %, unshelled seeds of 1.15 %, total losses of 2.51 %, sheller productivity of 155.98 × 10^{-3} Mg/h, unit energy consumption of 2.87 kW·h/Mg, cleaning efficiency of 99.06 % and criterion cost of 42.17 LE/Mg at feed rate of 160 kg/h, box speed of 1.4 m/s, moisture content about 17.12 % w.b. and air velocity of 8.37 m/s. But before modification shelling efficiency was of 95.32 %, damaged seeds of 6.12 %, unshelled seeds of 4.68 %, total losses of 10.8 %, sheller productivity of 89.20 × 10^{-3} Mg/h, unit energy consumption of 3.47 kW·h/Mg, cleaning efficiency of 98.88 %, and criterion cost of 84.93 LE/Mg at feed rate of 100 kg/h and the other studied operating conditions.

Introduction

The yield of peanut crops that generate a cash return quickly to the farms where it is a major export crops consumes about 65-70 %. Output locally and make it 30-35 % (BMA, 2004). Kittichai (1984) developed a power-operated groundnut sheller. He found that the best performance of the sheller was achieved at 20 mm clearance and shelling bar speed of 180 rpm. At these parameters the machine capacity, shelling efficiency and percentage of breakage were 210.5 kg-kernels/h, 98 % and 5.3 % respectively. The power consumption of the sheller ranged from 1.0 to 1.1 kW. Gore *et al.* (1990) classified the groundnut shellers, depending on their power source, into manually operated and power-operated. Based on shelling action, the shellers could be classified into reciprocating type and continuous or rotary type. The manually operated groundnut shellers could be classified into three subclasses a) semi rotary type sheller, b) hand-operated sheller with shelling cylinder which was rotated by hand, and c) foot operated sheller. Abou El-Kheir and Shoukr (1993) studied the effect of some operating parameters of sheller and natural properties of crop material on shelling efficiency. The increase in number of drum beaters from 4 to 8 increased the number of hits per unit time and increased shelling efficiency from 74 to 80.6 % at drum speed of 1.83 m/s and from 87 to 92.5 % at drum speed of 4.58m/s. Shelling efficiency, using rubber drum, was less than that of both steel and wooden drum. Singh (1993) tested two types of concave in manual sheller, the first was wire mesh concave and the second was slotted grate. Shelling capacity with wire mesh concave was higher (86 kg/h) compared to that of slotted grate (60 kg/h). This is due to increased opening area. For wire mesh concave the shelling efficiency ranged from 83 to 89 % compared to the slotted type, which ranged from 82 to 84 %. Also, the percentage of breakage ranged from 3.7 to 6.7 % and from 8.4 to 12.6 % for wire mesh and slotted grate respectively. Younis *et al*. (1997) developed a peanut sheller. Results of the modified sheller evaluation indicated that breakage was reduced from 57 to 54 %, cleaning efficiency increased from 67 to about 96 %, and separation efficiency increased from 28 to 93 % compared to the original sheller. The total loss was also decreased from 57 to about 4 % compared to the original sheller. Helmy (2001) designed, built and evaluated a reciprocating sheller to study the effect of some operating parameters on shelling peanut from the pods. He concluded that, the peanut shelling efficiency was 95.44 % at about 17.12 % w.b. moisture content when the box speed, the clearance and feed rate were 1.4 m/s, 18mm and 80 kg/h respectively. The lowest value of total cost of 64 LE/Mg was obtained at the same operating conditions. The specific objectives of the present study are directed to the following:

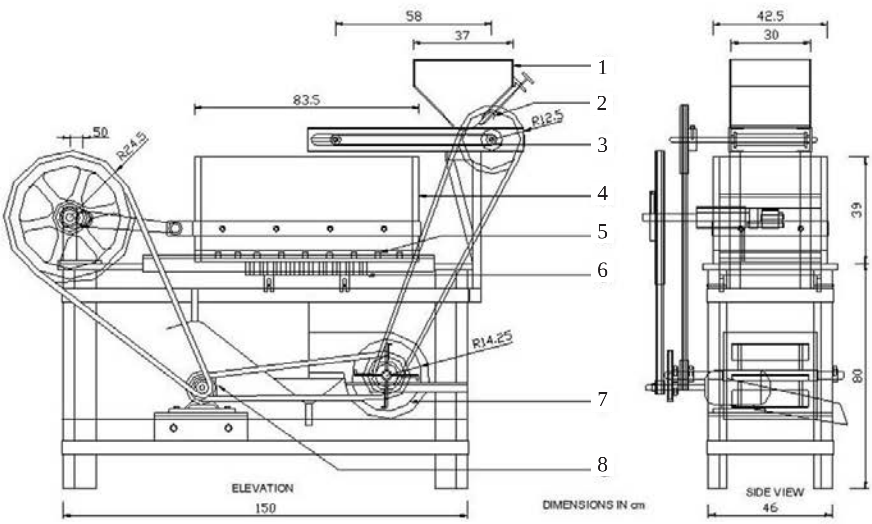
a) To specify the optimum conditions of peanut sheller before and after modification.
b) To increase the sheller productivity.
c) To reduce the total losses percent.
d) To lower costs per production unit.

Fig. 1 Elevation and side view of the reciprocating peanut sheller before modification



1 Feeding and shelling box (wood), 2 Wooden gates (wood), 3 Wooden strips (wood), 4 Shelling screen (wood), 5 Blower (metal), 6 Steel and wooden frame, 7 Electric motor

Fig. 2 Elevation and side view of the reciprocating peanut sheller after modification



1 Feeding hopper (wood), 2 Gate, 3 Conveyor belt (rubber), 4 Shelling box (wood), 5 Wooken strips (wood and rubber), 6 Shelling screen (wood and rubber), 7 Blower (metal), 8 Electric motor

Materials and Methods

The reciprocating peanut sheller has two function units for shelling and cleaning. The main parts of peanut sheller are shown in **Fig. 1**. The sheller consists of the following parts: Feeding and shelling box was constructed from wood and steel sheets. The two walls of the box were adjusted to obtain the proper slope for sliding the samples smoothly towards the feed opening. The feed rate of sample could be controlled through two gates fixed on the sides of the feed box walls. The bottom section of the shelling box was provided with fixed wooden strips for enhancing shelling process. The shelling box was driven by using a crank having a radius of 5 cm. That results in box stroke length of 10 cm. Meanwhile, the box speed was changed by using different pulleys varying in their diameters. To determine the reciprocating speed of the shelling box, the crank rotational speed was measured by a tachometer expressed in rpm, and it was converted to a linear velocity in terms of m/s. The shelling screen was fixed under the feed box and the clearance between the feed box and shelling screen could be adjusted by using four bolts moving the screen in perpendicular direction. The screen is of 45 cm length and

35cm width and made of a number of wooden strips with the dimensions of 2 × 3 × 30 cm. The blower (centrifugal type) has four straight blades and two inlet openings. The inlet openings are of circular shape of 28.5cm diameter, while the outlet opening is of rectangular shape of 16 × 39 cm. On the two inlets, there were two gates for controlling airflow rate. Air velocity was measured by using a digital vane-probe anemometer (Model: BREMI-BRI 5080-USA), which reads the velocity directly in m/s. The frame was constructed from wood, steel angles and steel sheets. The machine is powered by electric motor.

Modification:

The two gates in shelling box were eliminated and altered by a conveyor belt to increase the total friction area of shelling box and facilitate the feeding rate. The numbers of wooden strips of shelling box were doubled to increase the total friction area. While the wooden strips of shelling screen and shelling box were covered by rubber to minimize seed damage (**Fig. 2**). The dimensions of pods and seeds forms are considered important as limiting factors in passing the seed and the hull between the screen strips grate holes and in determination of clearance between box bottom and separating screen. For all experiments, this clearance was selected at constant value of 18mm according to study of the physical properties of the same variety by Helmy, 2001. The studied parameters were; three levels of moisture content (11.6, 17.2 and 23.52 % w.b.), three levels of box speed before and after modification (1.0, 1.4 and 1.7 m/s), three levels of feed rate before modification (80, 100 and 120 kg/h) and after modification (140, 160 and 180 kg/h) and three levels of air velocity (6.25, 8.37 and 10.11 m/s). All the experimental treatments were repeated three times and the averaged values of the investigated parameters were taken.

The technical indices in the present investigation were determined as follows:

Moisture content of peanut pods was calculated according to ASAE, 1989 as follows:

Pods moisturecontent, % = AC + BD .... (1)

Where:

A: moisture content of seeds, %;

C: seeds in average, %;

B: moisture content of hull, % and

D: hulls in average, %.

Total shelling losses are defined as the sum of the damage percentage and unshelled seeds. They were determined according to relations used by Gore *et al*., 1990:

Damage percentage, % = (Mass of damaged seeds / Total mass of seeds) × 100 .... (2)

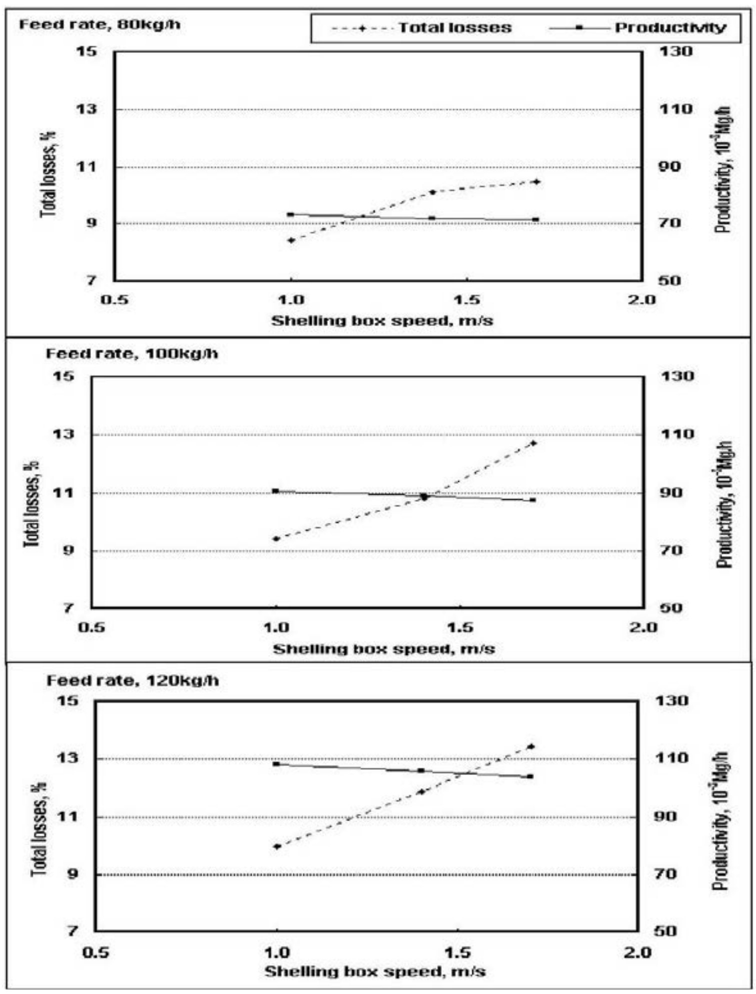
Unshelled seeds percentage, % = (Mass of unshelled seeds / Total mass of seeds) × 100 .... (3)

Shelling efficiency was determined according to the formula by El-Sayed, 1992:

Shelling efficiency % = 1 − (Mass of unshelled seeds / Total mass of seeds) × 100 .... (4)

Ammeter and voltmeter were used for measuring the current strength and potential difference respectively. Readings of Amperes and Volts were taken before and during each treatment. The power consumption was calculated by using the following formula (Lockwood and Dunstan, 1971):

Fig. 3 Effect of shelling box spend on total losses and productivity before modificaion at pods moisture content about 17.12 % w.b. and various feeding rates



Total power consumption, kW = $\sqrt{3}$ */ 1000 (I.V. cosθ. η)* ....(5)

Where:

I: current strength, Amperes;

V: potential difference,

cos θ: power factor, decimal (being equal to 0.71) and

η: mechanical efficiency of motor assumed to be 80 %.

The unit energy requirement was calculated by using the following equation:

Unitenergy requirement, kW × (h / Mg) = Total power consumption (kW) / productivity (Mg / h) ....(6)

Cleaning efficiency was determined according to the formula:

Cleaning efficiency, % = 1 − (Mass loss of cleaning seeds / Total mass of cleaning seeds) × 100...(7)

The total (criterion) cost of the sheller operating was estimated by using the following equation (Awady *et al*., 1978):

Total cost, LE / Mg = unit operating cost + unit worth of shelling losses.....................................(8)

Unit operating cost was determined by using the following equation:

Unit operating cost, LE / Mg = [Sheller cost (LE/h) / productivity (Mg/h)] ....(9)

Peanut sheller costs were determined as follows:

Fixed Costs:

a) Depreciation:

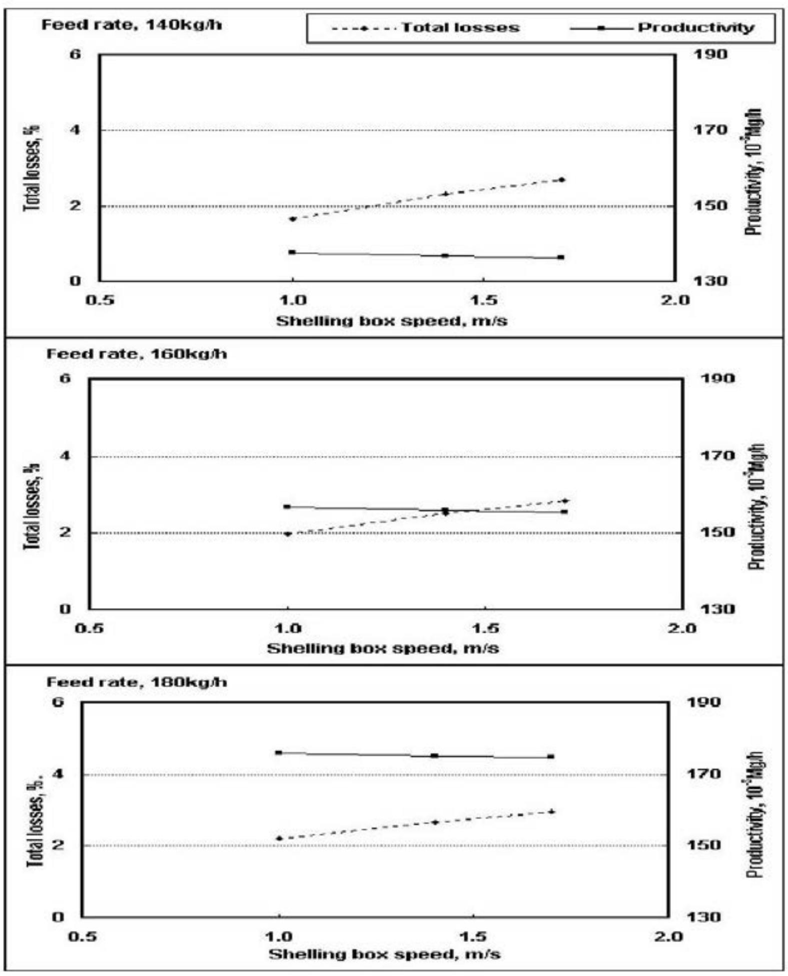


Fig. 4 Effect of shelling box spend on total losses and productivity after modificaion at pods moisture content about 17.12 % w.b. and various feeding rates

Declining balance method was used to determine the depreciation (Hunt, 1983). In this method the depreciation value is different for every year of the machines life. Depreciation value was determined by using the following **Eqn**:

$D = V_n - V_{n+1}$, *L. E. / Yr.*........ (10)

$V_n = P \times [(L - X) / L]^n$, *L. E. / Yr.* .... (11)

$V_{n+1} = P \times [(L - X) / L]^{n+1}$, *L. E. / Yr.* .... (12)

Where:

D: value of depreciation charged year, (*n+1*);

P: purchase price, L. E.;

L: time between buying and purchasing, Yr.;

n: number representing age of the machine in year at the beginning of year;

V: remaining value at any time and

X: ratio of depreciation rate for used machine (the maximum rate is 1.5).

b) Interest on investment, shelter taxes and insurance:

They were estimated as 12 % of the remaining value.

Operating Costs:

a) Repairs and maintenance:

For machinery, repairs and maintenance is about 7 % as a percent of purchase price.

b) Electricity cost.

c) Lubricant cost.

d) Labor cost.

Results and Discussion

Performance of Peanut Sheller:

In order to establish the optimum operating conditions for the peanut sheller before modification, **Fig. 3** illustrates the total shelling losses and productivity as affected by shelling box speed at various feeding rates. It is revealed that the optimum operating conditions for the sheller before modification were obtained at feed rate of 100 kg/h and shelling box speed of 1.4 m/s. While

Fig. 5 Effect of feeding rate on damaged, unshelled seeds and tatal losses for the sheller before and after modification at pods moisture content about 17.12 % w.b. and shelling box speed of 1.4 m/s

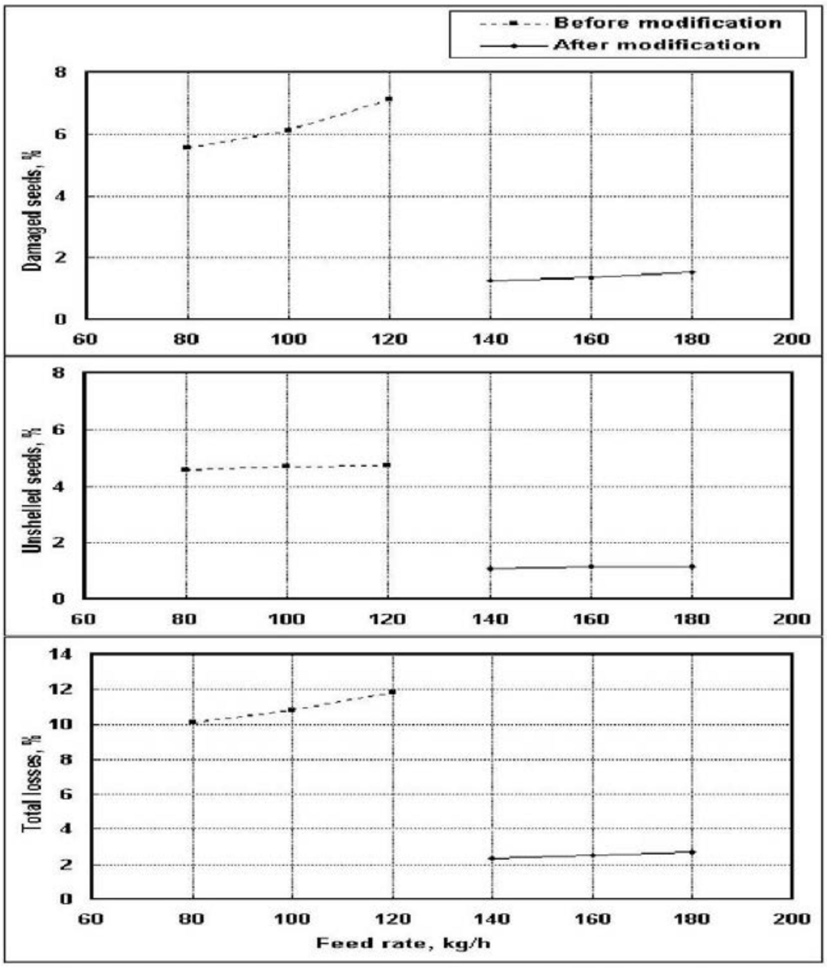
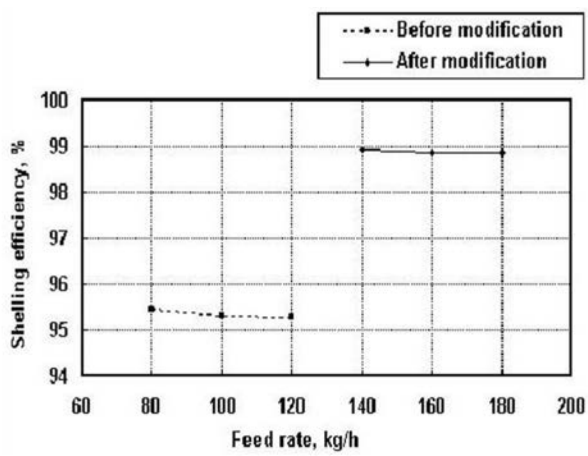


Fig. 6 Effect of feeding rate on shelling efficiency at pods moisture content about 17.12 % w.b. and shelling box speed of 1.4 m/s



after modification, **Fig. 4** illustrates that total shelling losses and productivity as affected by shelling box speed and various feeding rates. It is seen that the optimum operating conditions for the sheller after modification were obtained at feed rate of 160 kg/h and shelling box speed of 1.4 m/s. However, the suitable moisture content of peanut pods was about 17.12 % w.b. for the sheller before and after modification.

Total Losses:

The damaged seeds percentage was increased by increasing feed rate for the sheller before and after modification. The damaged seeds ranged from 5.55 to 7.13 and 1.25 to 1.54 % at feed rate ranges of 80-120 and 140-180 kg/h, box speed of 1.4 m/s and moisture content about 17.12 % w.b. for the sheller before and after modification respectively. The percentage of damaged seeds for the sheller after modification is less than that before modification. This may be due to that before modification: box speed was unqualified to cover feed rate successfully. After modification: the conveyor belt controlled the feed rate to meet the box speed in the proper time, decreasing unshelled and damaged seeds. The unshelled seeds percentage was increased by increasing feed rate for the sheller before and after modification. The unshelled seeds ranges were 4.56-4.73 and 1.08-1.14 % at feed rate ranges of 80-120 and 140-180 kg/h at box speed of 1.4 m/s and moisture content about 17.12 % w.b. for the sheller before and after modification respectively. The percentage of unshelled seeds for the sheller after modification is less than that before modification. This may be due to the conveyor belt, which gave more uniformity of feeding rate in comparison with gate system. The total losses (damaged + unshelled seeds) percentage was also increased by increasing feed rate for the sheller before and after modification. The total losses

Table 1 The economical cost for producing one Mega gram of peanut seeds

Sheller machine	Feed rate, kg/h	Sheller productivity, Mg/h	Sheller operating cost, LE/h	Unit operating cost, LE/Mg	Total shelling losses, LE/Mg	Total cost, LE/Mg
Before modification	100	0.08920	4.14	46.41	38.52	84.93
After modification	160	0.15598	4.36	27.95	14.22	42.17

ranges were 10.11-11.86 and 2.33-2.68 % at feed rate ranges of 80-120 and 140-180kg/h at box speed of 1.4 m/s and moisture content about 17.12 % w.b. for the sheller before and after modification respectively (**Fig. 5**).

Shelling Efficiency:

Shelling efficiency of peanut sheller was decreased by increasing feeding rate before and after modification. The shelling efficiency ranged from 95.44 to 95.27 and 98.92-98.86 % at feed rate ranges of 80-120 and 140-180 kg/h at box speed of 1.4 m/s and moisture content about 17.12 % w.b. for the sheller before and after modification respectively (**Fig. 6**). Increase of shelling efficiency after modification can be attributed to the existing of the conveyor belt, which increases the chance of pods to stay more time on the box strips as result shelling efficiency increase and increasing the friction area of shelling box.

Fig. 7 Effect of feeding rate on unit energy at pods moisture content about 17.12 % w.b. and shelling box speed of 1.4 m/s

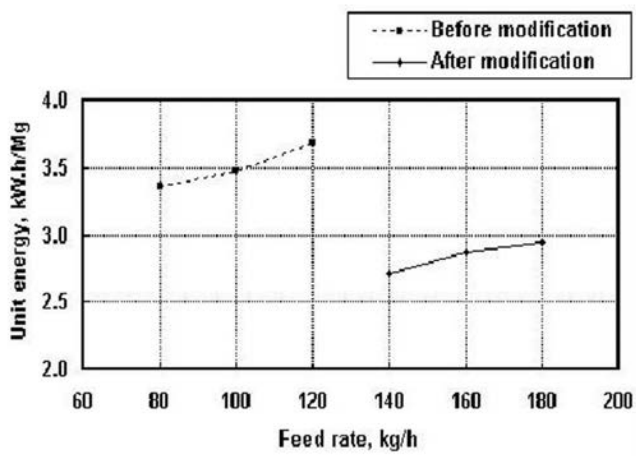
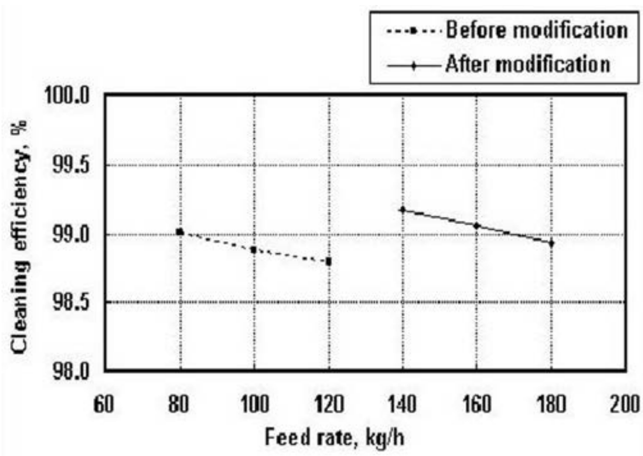


Fig. 8 Effect of feeding rate on cleaning efficiency at pods moisture content about 17.12 % w.b., shelling box speed of 1.4 m/s and air velocity of 8.37 m/s



Energy Requirements:

Unit energy values were increased by increasing feed rate for the sheller before and after modification. The unit energy ranges were 3.36-3.68 and 2.71-2.95 kW.h/Mg at feed rate ranges of 80-120 and 140-180 kg/h at box speed of 1.4m/s and sheller moisture content about 17.12 % w.b. before and after modification respectively (**Fig. 7**). The reduction in sheller unit energy values after modification can be attributed to the increase of sheller productivity.

Cleaning Efficiency:

Cleaning efficiency was decreased by increasing feed rate for the sheller before and after modification. The cleaning efficiency ranged from 99.01 to 98.79 and 99.17 to 98.93 % at feed rate ranged from 80 to 120 and 140 to 180 kg/h at box speed of 1.4 m/s, air velocity of 8.37 m/s and moisture content about 17.12 % w.b. for the sheller before and after modification respectively (**Fig. 8**). Increase of sheller cleaning efficiency after modification may be due to uniformity of feeding rate by using conveyor belt.

Cost Analysis:

Table 1 summarizes the economical cost for producing one Mega gram of peanut seeds. The total cost was deduced to determine the cheapest operating conditions. It can be concluded that the lowest value of total cost of 84.93 LE/Mg for the sheller before modification was obtained at feed rate of 100 kg/h, box speed of 1.4 m/s and moisture content about 17.12 % w.b. While after modification, the lowest value of total cost of 42.17 LE/Mg was obtained at feed rate of 160 kg/h under the same operating conditions.

Conclusion

For the duration of the current investigation, the main results gained are concluded in the following two points:

1. The performance of a reciprocating peanut sheller after modification was better than that before modification because the productivity was increased and the total losses (damaged + unshelled seeds) were decreased.
2. The applied recommendations for operating the reciprocating peanut sheller before and after modification can be concluded in the following: (under the **Table**)

REFERENCES

Abou El-kheir, M. M. and A. Z. Shoukr. 1993. Modelling of the action of mechanical shelling of peanut for different materials of beater drum. Misr J. Ag. Eng., 10(1): 123-135.

ASAE. 1998. Moisture measurement-peanuts. American Society of Agricultural Engineers, St. Joseph, Michigan. ASAE S410.1 DEC97: 560-561.

Awady, M. N. 1978. Tractors and farm machinery. Textbook. Ag. Mech. Dept., Faculty of Ag., Ain Shams Univ.: 164-167.

BMA. 2004. Bulletin of the Ministry of Agriculture. Serve and grow peanuts in the land of ancient and new, Agricultural Research Center, the National Programme for leguminous crops.

El-Sayed, A. S. 1992. A simple prototype of conical sheller of peanut seeds. Misr J. Ag. Eng., 9(2): 149-159.

Gore, K. L.; C. P. Gupta, and C. Singh 1990. Development of power operated groundnut sheller. AMA, 21(3): 38-44.

Helmy, M. A. 2001. Evaluation of a reciprocating peanut sheller. AMA, 32(4): 35-24:27.

Hunt, D. 1983. Farm power and machinery management. 8th Ed. Iowa State Univ. Press, Ames., U.S.A., : 59-71.

Kittichai, T. 1984. Development and test of a power-operated groundnut sheller. M. Eng. Thesis No. AE-84-11, Asian Institute of Technology, Bangkok.

Lockwood, F. B. and R. Dunstan 1971. Electric engineering principles. Meinemann Educational Books, L-td, London.

Singh, G. 1993. Development of a unique groundnut decorticator. AMA, 24(1): 55-64.

Younis, S. M.; H. A. Abdel-Mawla, and H. A. Farag 1997. Development of peanut sheller. Misr J. Ag. Eng., 14(1): 106-117.

■■

Performance parameter	Value		Increasing (+) or reduction (−), %
	Before modification	After modification	
Moisture content, % w.b.	17.12	17.12	-
Clearance, mm	18	18	-
Box speed, m/s	1.4	1.4	-
Air velocity, m/s	8.37	8.37	-
Feed rate, kg/h	100	160	+ 60.0
Productivity, Mg/h	89.20×10^{-3}	155.98×10^{-3}	+ 74.9
Damaged seeds, %	6.12	1.36	− 77.8
Unshelled seeds, %	4.68	1.15	− 75.4
Total losses (damaged + unshelled seeds), %	10.80	2.51	− 76.8
Shelling efficiency, %	95.32	98.85	+ 3.7
Unit energy, kW.h/Mg	3.47	2.87	− 17.3
Cleaning efficiency, %	98.88	99.06	+ 0.18
Criterion cost, LE/Mg	84.93	42.17	− 50.3

Development of Batch Type Multiplier Onion (Onion Aggregatum) Peeler with Centrifugal Discharge

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Abstract

Multiplier onion (Onion aggregatum) is consumed in large quantity in southern provinces of India. These are used in large quantities in the catering and pickling industries, creating a need for peeling equipment. Multiplier onion peeling is an essential step in producing many of the onion products such as dehydrated onions, onion powder, onion flavoring, onion salt, onion rings, and pickled and canned onions, which is a very tedious process. A batch type peeling machine suitable for farm-level operation was designed and tested for multiplier onion. The equipment consisted of a cast aluminum drum seated over a rotating disc. Inner surface of the drum and top surface of the lower disc are covered with corrugated rubber sheet which aids in the peeling process. The multiplier onion needs to have the ends cut with a sharp knife and soaked in clean water for a period of 10 min to assist the loosening of peel followed by air drying for 1-2 min to remove the surface water. Major operational parameters: speed of operation and abrasive surface on the drum were optimized for peeling efficiency, damage to the bulb and other performance parameters. The capacity of the peeler was about 50-60 kg/h. The peeling efficiency was about 92 percent with unpeeled and damaged percentage being 6 and 2 percent, respectively. The cost economics study revealed that the equipment had a saving in labour and cost to a tune of about 68 and 69 percent, respectively, with a payback period of 1.40 years. The equipment can be adopted by small and medium multiplier onion processing industries.

Introduction

Multiplier onion (Onion aggregatum) is consumed in large quantity in the southern provinces of India. Peeling is a time consuming process, as a result of which working women avoid this particular type of onion even though it is much preferred and reported to have many medicinal advantages. These onions are used in large quantity in the catering and pickling industries, creating a need for mechanized peeling equipment. The mean weight of multiplier onion bulb per plant is 75 g and the number of bulbs per plant ranges from 8-10. The moisture content of the bulb was about 84.5 percent (w.b). The pungency of the multiplier onion is around 17 micro mole per gram and was grouped as strong onion as per the standard given by Schwimmer and Weston (1961). They reported that strong onions produce 16-20 micromoles of pyruvic acid per gram of onion.

Multiplier onion peeling is an essential step in producing many of the products such as dehydrated, powder, pickled and canned products. Several methods can be used for peeling multiplier onions. The common methods used in modern processing industry are lye treatment and flame peeling. Lye peeling and flame peeling methods are harsh and are not suitable for many multiplier onion products. In lye peeling or flame peeling, onions are abraded and then treated in a hot solution of caustic soda or burnt by passing through a furnace. Burnt skins are removed by scrubbing them with brushes. These methods suffer from a number of disadvantages. First, they produce incompletely peeled multiplier onions, that is, the core of the root remains with the onion bulb and require further processing. Chemical and flame treatment tend to damage the onions and their flavor compounds which affect the quality of some products. These technologies are relatively expensive, inefficient, and generally create unpleasant working conditions. Compared to the above two methods, mechanical peeling has many advantages. The tip and the root of the onion are physically cut. There is no undesirable chemical or thermal to the onions thus resulting in a higher quality product. This is important for onions that are pickled or used as fresh ingredient for canned products. Hence a batch type mechanical peeler for multiplier onion bulbs with centrifugal discharge was developed for the benefit of small onion processing industries.

Materials and Methods

Preparation of Multiplier Onion for the Experiments

Pungent Multiplier onion (Co-3) was procured from the local vegetable market. Damaged/spoiled multiplier onions were discarded and the good multiplier onions were used for the studies.

Determination of Frictional Properties of Multiplier Onion

Scientists have directed great efforts in evaluating the basic physical properties of agricultural materials and have pointed out their practical utility in the machine and structural design and in the process and control engineering. (Maw *et al*., 1996; Viswanathan *et al*., 1997). Agricultural materials especially bulbs pose special problem in determining their physical properties because of their diversity in the shape, size, moisture content and maturity indices.

The design oriented frictional properties of multiplier onion such as rolling angle, coefficient of friction were determined by the following standard methods. Based on the size of the bulblets, the onions were divided into various size groups: 12 mm, 14 mm, 18 mm and 20 mm. These were the commercial sizes commonly used in the trading of the multiplier onion in the local and international markets.

Moisture content: Moisture content was determined by AOAC oven method (AOAC, 1975) at 60 ºC expressed in percent, wet basis.

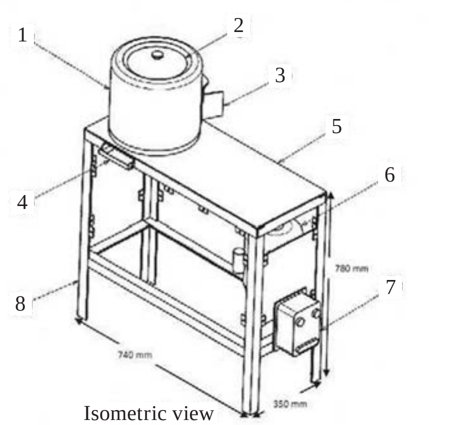
Size: Size is the measure of physical dimension of the object. Fruits and vegetables are irregular in shape and a complete specification of their form theoretically requires an infinite number of measurements. From practical point of view, measurements of several mutually perpendicular axes are to be taken. However the measurements along major and minor axes were taken for describing the size of the multiplier onion (Mohsenin, 1986).

Rolling resistance: To determine the rolling angle, the bulb to be tested was kept at the center of the working surface, (horizontal platform) in the most stable position (on their base) to prevent toppling over (top upwards). Rolling resistance was determined for various sizes of multiplier onion (Buyanov & Voronyuk, 1985).

Sliding Coefficient of static friction: Coefficient of static friction is the ratio of the force required to slide the bulb over a surface divided by the normal force pressing the bulb against the surface. Coefficient of friction was determined for multiplier onion bulbs on three surfaces: rubber, galvanized steel and plywood. (Oje and Ugbor, 1991). When the tangential force overcomes the frictional force between two surfaces, then the surfaces begin to slide relative to each other. In the case of a body resting on a flat surface, the body starts to move. The coefficient of sliding friction is generally lower than the static coefficient of friction.

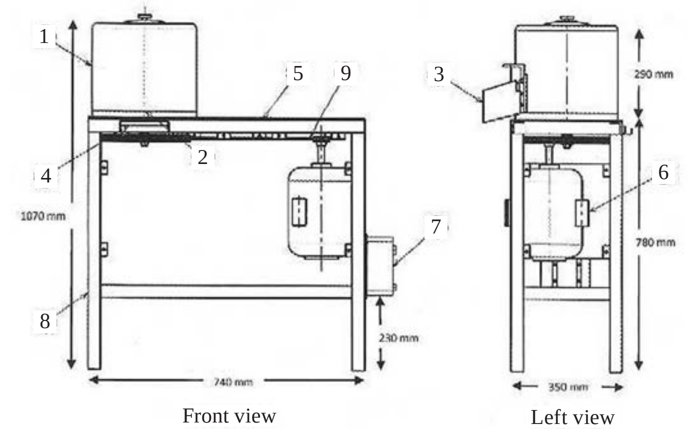
Pretreatment for multiplier onion peeling: Optimization studies were carried out to study the effect of soaking time on the ease of peeling

Fig. 1 Isometric view of multiplier onion peeler



1 = Peeling chamber; 2 = Removable inlet cover; 3 = Discharge chute for peeled multiplier onion; 4 =Outlet for peeled skin; 5 = Working platform; 6 = Motor; 7 = Starter; 8 = Outer frame

Fig. 2 Front view and side view of multiplier onion peeler



1 = Peeling chamber; 2 = Removable inlet cover; 3 = Discharge chute for peeled multiplier onion; 4 =Outlet for peeled skin; 5 = Working platform; 6 = Motor; 7 = Starter; 8 = Outer frame

of multiplier onion The multiplier onion after cutting the top and the base was subjected to hand peeling to know the effect of the soaking on the loosening of the skin, so that the time of the soaking for mechanical peeling could be optimized. The standardization of the peeling parameters were carried out for the following grades of multiplier onion, which are commercially available in the market: 12 mm; 14 mm; 18 mm and 20 mm

Description of Batch Type Multiplier Onion Peeler

Based on the optimized parameters, a batch type multiplier onion peeler with centrifugal discharge was developed at the Research workshop of Regional Centre of Central institute of Agricultural Engineering, Coimbatore, India (**Figs. 1** and **2**).

The equipment consists of the following parts:

1. Peeling drum: The equipment consists of a cast aluminum alloy drum of size of 300 mm diameter and height 290 mm, and the drum is seated over a 300 mm diameter disc. The drum is mounted on a bearing shaft to enable smooth rotation (**Figs. 3** and **4**). Two bumps are provided on the circular base to break rotary movement of the multiplier onion on the lower portion and provide swirling action so that efficient peeling takes place.
2. Removable inlet cover: The outer inlet cover is used to cover the aluminum alloy drum when the equipment is in operation, so that the multiplier onion during the process of peeling does not spill out of the unit.
3. Discharge chute for peeled multiplier onion: An opening of 140 mm × 100 mm is used for discharge of peeled multiplier onion. The discharge gate is raised at the end of each peeling operation enabling centrifugal ejection of the product by the rotary motion of the disk. Manual unloading and separation of the peelings and product are avoided by this method, providing for faster and higher throughput operations. The outlet opening is located in proximity to the periphery of the abrasive disk and centrifugal force expels peelings from the processing chamber during the peeling operations.
4. Working platform. The working platform is used for keeping the samples to be peeled
5. Motor with a starter: A one hp single phase electrical motor with starter is used for the operating the equipment.
6. Outer frame: The whole assembly of drum and disc is mounted on a M. S. outer frame 740 mm × 350 mm × 780 mm

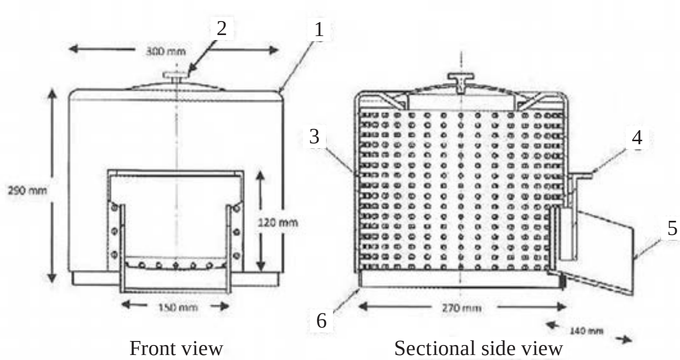
Optimization of Time of Soaking for Easy Peeling of Multiplier Onion

Soaking of multiplier onion eased the peeling operation. To standardize the time of soaking, 100 grams of different grade multiplier onion 12 mm, 14 mm dry, 18 mm dry and 20 mm wet were subjected to various soaking times of 5, 10, 15, 20 and 25 min for all the grades. After the fixed soaking time, the samples were removed and peeled manually and the time noted. The same person was used throughout the experiment with sufficient time in between two samples.

Optimization of the operational parameters viz., speed of operation of peeling drum and abrasive surface used as peeling material:

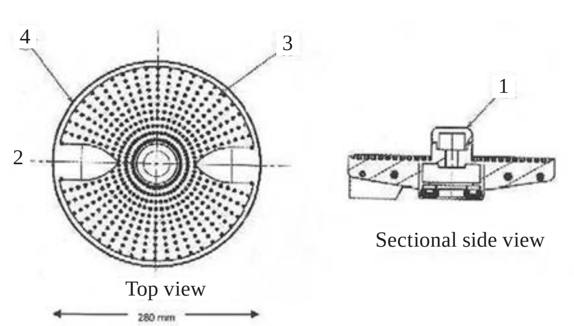
The peeling efficiency basically depends on the right choice of the abrasive material and the speed of operation. Different abrasive materials viz., plastic brushes of 2 mm, CI abrasive chips glued on the revolving disc and along inner wall and bottom surface of the peeling drum and rubberized mat were experimented. The rpm of the disc was reduced from 1,440 (1 hp single phase motor) to required speed by using a belt and pulley type of re-

Fig. 3 Front view and sectional cross view of the peeling drum



1 = Peeling drum; 2 = Removable inlet cover; 3 = Peeling side surface; 4 = Sliding discharge cover; 5 = Discharge chute for peeled multiplier onion; 6 = Circular base plate

Fig. 4 Top view and sectional end vie of the peeling drum



1 = Drive spindle; 2 = Bumps; 3 = Lower peeling surface; 4 = Hub

duction system. Different speeds of rotation of the peeling drum viz., 720 rpm, 600 rpm, 300 rpm and 150 rpm were evaluated. The best abrasive surface was optimized based on percentage of multiplier onion peeled, unpeeled and damaged with respect to various speed of rotation of the peeling drum. The multiplier onion peeler was developed at the optimized abrasive surface and speed of operation.

Cost Economics

The data and information collected both on conventional method of peeling of multiplier onion and by using multiplier onion peeler were analyzed for cost of peeling. The cost of the multiplier onion peeler was assumed to be Rs 20,000 ($ 400) with the annual usage of 540 h. The life of multiplier onion peeler was 5 years with the salvage value of 10 percent. Straight line method was used for cost economic calculation with rate of depreciation of 10 percent. The fixed and variable costs for operating of the multiplier onion peeler were calculated as per the procedure enumerated by RNAM (Anon., 1983). The breakeven point and payback period of the equipment were also calculated.

Statistical analysis:

All the experiments were performed three times. Data were analysed by one way analysis of variance (ANOVA) to test the significance for peeling of multiplier onion.

Results and Discussion

Frictional Properties of Multiplier Onion (Co-3 Variety)

The rolling angle and coefficient of friction of the multiplier onion were recorded based on the different surfaces viz., rubber, plywood and galvanized steel. All the commercial grades viz., 12 mm, 14 mm, 18 mm and 20 mm were evaluated for these parameters. The average values are depicted in the **Table 1**.

It is seen that the rolling resistance increased with the increase in the size of the multiplier onion, whereas the coefficient of friction reduced with the size. Galvanized iron had the least rolling resistance followed by plywood and rubber. The frictional properties are useful to select the optimum peeling media during development of the equipment.

Optimization of Time of Soaking for Ease of Peeling of Multiplier Onion

Soaking of multiplier onion eased the peeling operation. The time required for peeling is given in **Table 2**. From the table it is seen that with the increase in the soaking time the time taken for peeling reduced. Beyond 10 minutes of soaking, there was no significant reduction in the peeling time. Hence, soaking time of 10 minutes was standardized for multiplier onion for mechanical peeling. By visual observation, it was also seen that when the soaking period was more than 10 minutes, there was a tendency of water to diffuse into the outer skin, which was not desirable.

Standardization of the Operational Parameters of Multiplier Onion Peeler

The operational parameters viz., the rpm of peeling drum, and type of abrasive material used on the inner surface of the peeling drum

Table 1 Rolling resistance and Coefficient of friction of multiplier onion of different sizes

Multiplier Onion Size	Rolling resistance, degree			Coefficient of friction		
	Rubber	Galvanized iron	Plywood	Rubber	G.I.	Plywood
12 mm	25.33 ± 0.57	21.07 ± 0.61	22.07 ± 0.23	1.01 ± 0.04	0.89 ± 0.03	0.96 ± 0.03
14 mm	26.15 ± 0.61	22.18 ± 0.47	23.96 ± 0.31	0.93 ± 0.02	0.83 ± 0.02	0.89 ± 0.02
18 mm	28.33 ± 0.55	24.56 ± 0.36	26.84 ± 0.19	0.88 ± 0.01	0.79 ± 0.01	0.83 ± 0.02
20 mm	31.58 ± 0.67	26.15 ± 0.41	30.33 ± 0.23	0.84 ± 0.01	0.74 ± 001	0.80 ± 0.02

Table 2 Optimization of the time of soaking to ease peeling of multiplier operation

Grade	12 mm dry		14 mm dry		18 mm wet		20 mm wet	
ST, min	Quantity (gms)	PT, min	Quantity (gms)	PT, min	Quantity (gms)	PT, min	Quantity (gms)	PT, min
Control	100	8.0[a]	100	7.9[a]	100	7.1[a]	100	7.0[a]
5	100	7.0[b]	100	7.5[b]	100	6.5[b]	100	6.3[b]
10	100	5.5[c]	100	5.3[c]	100	5.1[c]	100	4.7[c]
15	100	5.3[c]	100	5.2[c]	100	5.0[c]	100	4.6[c]
20	100	5.3[c]	100	5.2[c]	100	4.9[c]	100	4.5[c]
25	100	5.2[c]	100	5.0[c]	100	4.8[c]	100	4.5[c]
CD (0.05)		3.87		3.17		0.333		2.18

ST = Soaking time; PT = Peeling time

were standardized by actual experimentation. A batch of two kg of multipler onions with both ends cut and soaked for a period of 10 minutes (Ravindra Naik *et al.*, 2010) were fed in the equipment and operated at different speeds and with different abrasive materials coated on the inner surface of the drum. The equipment was operated for a period of 10 minutes (**Fig. 5**). The data are depicted in the **Figs. 6, 7** and **8**. From **Fig. 6**, it is seen that, for the plastic brushes, the best results were obtained at 300 rpm, where it gave 88 percent peeled, 6 percent unpeeled and 6 percent damaged multiplier onion. In the case of CI abrasive chips, it was 85 percent peeled, 5 percent unpeeled and 10 percent damaged multiplier onion at 300 rpm (**Fig. 7**). The best results were obtained by using rubberized mat, which gave 92 percent peeled, 6 percent unpeeled and 2 percent damaged multiplier onion (**Fig. 8**). In general the best results for all the three materials were obtained at 300 rpm. As the speed increased from 300 to 720 rpm, the percentage damage increased continuously. But at a lower speed of 150 rpm, although the percentage damage was lower or on par with that of 300 rpm, the percentage unpeeled was high. Thus, keeping a balance between the percentage peeled, unpeeled and damaged, the best results were obtained at 300 rpm for rubberized mat surface (**Fig. 9**) and it was adopted in the final design of the equipment

Unpeeled Multiplier Onion Sample Machine Peeled Multiplier Onion Sample

Cost economics of the equipment: Continuous long run trials of the equipment were carried out to obtain the cost analysis of the equipment (**Fig. 10**).

A batch of 2 kg of multiplier onion could be peeled in 2 minutes, giving the capacity of the equipment as 50-60 kg/h. The fixed cost was Rs. 5,450/year ($109/year) and working cost Rs. 20,625-22,000/year ($375-

Fig. 5 View of the multiplier onion peeler

Fig. 6 Performance evaluation of batch type multiplier onion peeler with plastic brushes as abrasive peeling media

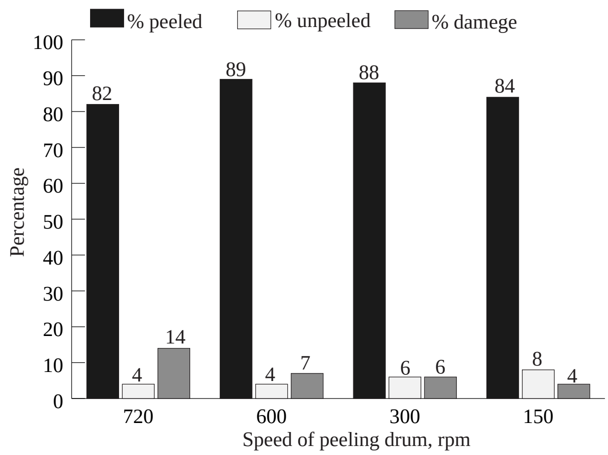


Fig. 7 Performance evaluation of batch type multiplier onion peeler with CI chips as abrasive peeling media

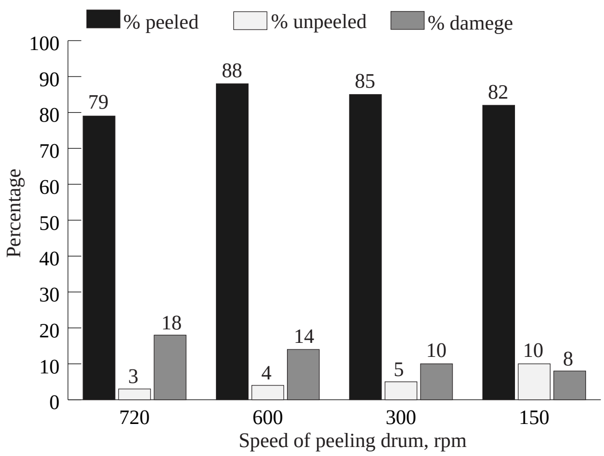
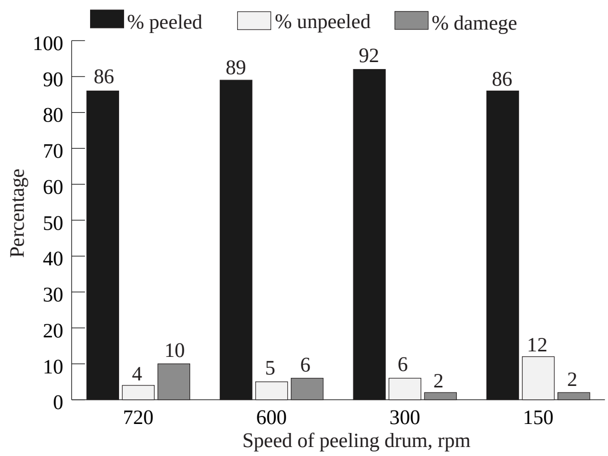


Fig. 8 Performance evaluation of batch type multiplier onion peeler with rubberized mat as abrasive peeling media



400/year). The cost of peeling was Rs. 1,250 per tonne ($25 per tonnes). The savings in cost and a savings in time was about 68 and 69 percent, respectively. The breakeven point of the developed multiplier onion peeler was 38.50 percent of annual utility and the payback period was 1.40 year. Thus, this equipment could be adopted by small and medium multiplier onion processing industries

Conclusion

Soaking time of 10 minutes was standardized for soaking of the multiplier onion for mechanical peeling. The best results were obtained by using a rubberized mat, which gave 92 percent peeled, 6 percent unpeeled and 2 percent damaged multiplier onion (**Fig. 8**). A peeling drum with 300 rpm gave the best results for all the three materials. A multiplier onion (Onion aggregatum) peeler of 50-60 kg/h has been developed with these optimized parameters for small and medium processing industries. The peeling efficiency was 92 percent with unpeeled and damaged percentage to the tune of 6 and 2 percent, respectively.

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REFERENCES

AOAC. 1975. Official methods of analysis, (12th ed.). Association of Official Analytical Chemists, Washington, DC. pp. 1015.

Boyer, E. F. 1960. U.S. Patent No. 2,961,023. U.S. Patent Office.

Maw, B. W., Y. C. Hung, E. W Tollner, D. A. Smittle, and B. G Mullinix. 1996. Physical and mechanical properties of fresh and stored sweet onions. Transactions of the ASAE. 39 (2): 633-637.

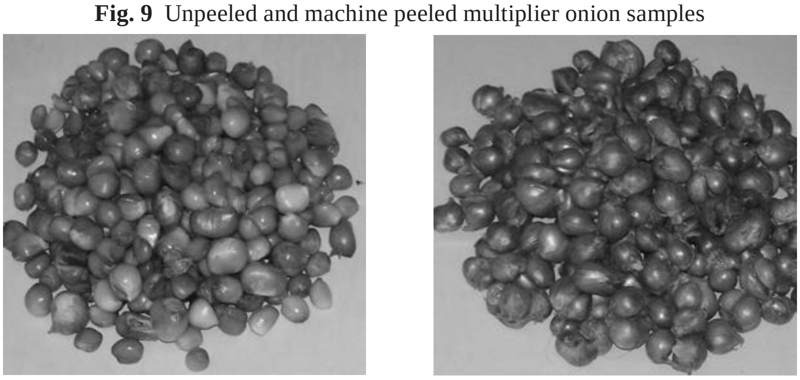
Mohsenin, M. M. 1986. Physical properties of plant and animal material. Gordon and Breach Science Publications, New York.

Ravindra Naik, S. J. K. Annamalai, and Dawn C. P. Ambrose. 2007. Pretreatment of multiplier onion for peeling. Presented at International Conference on Agricultural Engineering, Hersonissos, Crete, Greece, 23-25 June, 2008 pp. P-129.

RNAM Regional Network for Agricultural Machinery. 1983. Test codes and Procedures for Farm Machinery. Technical Series No.12. Bangkok, Thailand. p. 219.

Viswanathan, R., T. Pandiyarajan, and N. Vardaraju. 1997. Physical and Mechanical properties of tomato fruits related to pulping. J Food Sci. Technology. 34(6): 537-539.

Fig. 9 Unpeeled and machine peeled multiplier onion samples



Unpeeled multiplier onion sample

Machine peeled multiplier onion sample

Fig. 10 Continuous long trials of batch type multiplier onion peeler with centrifugal discharge

Design, Fabrication and Testing of Worm Sieving Machine for Commercial Production of Vermi-compost

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Abstract

Soil health and grain quality are the indicators of sustainability of agriculture. Obviously, there is need to promote the use of organic fertilizers by reducing dependence upon chemical fertilizers. The present study has been aimed to design, fabricate and test the worm sieving machine for vermi-compost production. Disproportionate weight theory was applied to produce jerk during manual and motorized operation. The maximum output (7.4 q/h) and maximum sieving efficiency (98 %) was found under motorized operation as compared to those (3.6 q/h and 96 %, respectively) under manual operation. Financial gain of US$ 7.73 and US$ 6.87 per tonne was observed under motorized and manual operation respectively over conventional method.

Introduction

India's green revolution was ushered in by high yielding varieties of cereals followed by intensive tillage, use of chemical fertilizers, pesticides and irrigation water etc. But to carry on with ever-increasing population, India needs evergreen revolution. The intensive use of chemical fertilizers, though has increased the productivity, but caused toxicity in grains besides adverse effect on soil and ground water quality. Thus there is need to increase agricultural production through judicious use of fertilizers. No doubt, organic farming serves a better option. But organic fertilizers when used in combination with inorganic fertilizers, dependence on inorganic fertilizers will be reduced leading to saving of money and good health of soil with better grain quality.

Production of vermi-compost can serve this purpose. Existing system of vermi-compost production is being supported by manual separation of worms through wire-net sieve from the compost which is not only time consuming rather dropping of worms and its mortality increases with poor output efficiency. Mechanization of worm separation process may help in ensuring better profitability and there are opportunities for popularization of this cost effective machine among farmers. Studies conducted abroad on worm separation techniques from vermi-compost are not ideal for local soil in Indian condition (Stevenson, 1980; Slobadian, 1999; and Curro, 2003).

Therefore, it has been planned to design, fabricate and test the worm sieving machine for commercial production of vermi-compost.

Methods and Materials

For success of worm sieving machine, problems of conventional worm sieving techniques were identified and the behaviour of worms was studied. A hypothesis was generated for design and development of machine and materials for fabrication were selected. The machine was fabricated and then tested for generation of data under manual and motorized operation. The details of the machine parts are given in **Fig. 1**. A view of fabricated worm sieving machine is shown in **Fig. 2**.

Problem Identification of Conventional Method

A survey was conducted on 30 compost producers to assess the following parameters for design and development of machine:

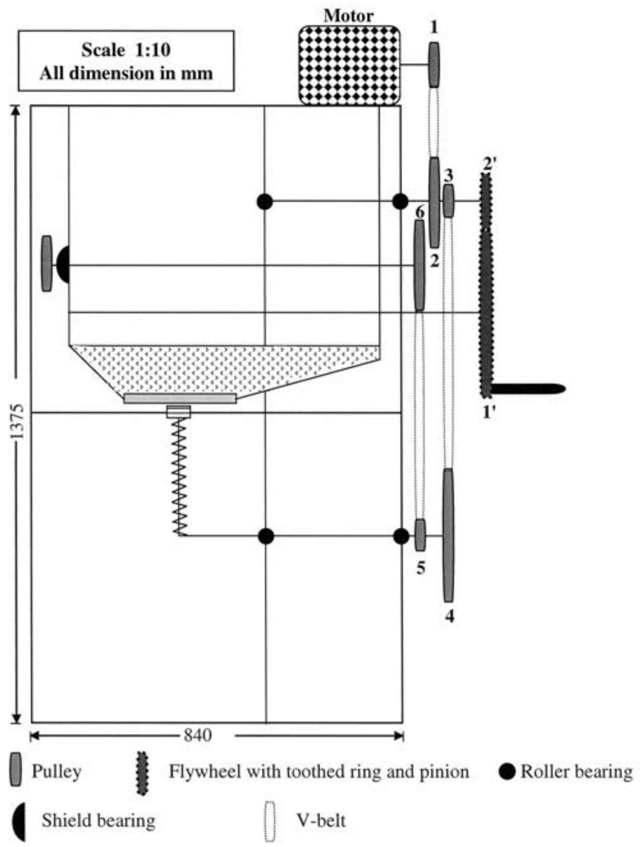
- High labour requirement
- Low output- a barrier for profitable commercial production
- High worm mortality rate

Study of Worm Behaviour

For determination of shape of sieve hole, it was essential to study the worm behaviour and its response towards stimuli like light, touch and jerk. If the worm had a tendency to get in a coiled shape after applying stimuli, the shape of hole of sieve would have been rectangular for restricting the worms fromt drop-

Fig. 1a Schematic diagram of the worm sieving machine

Engineering Drawing of the components:

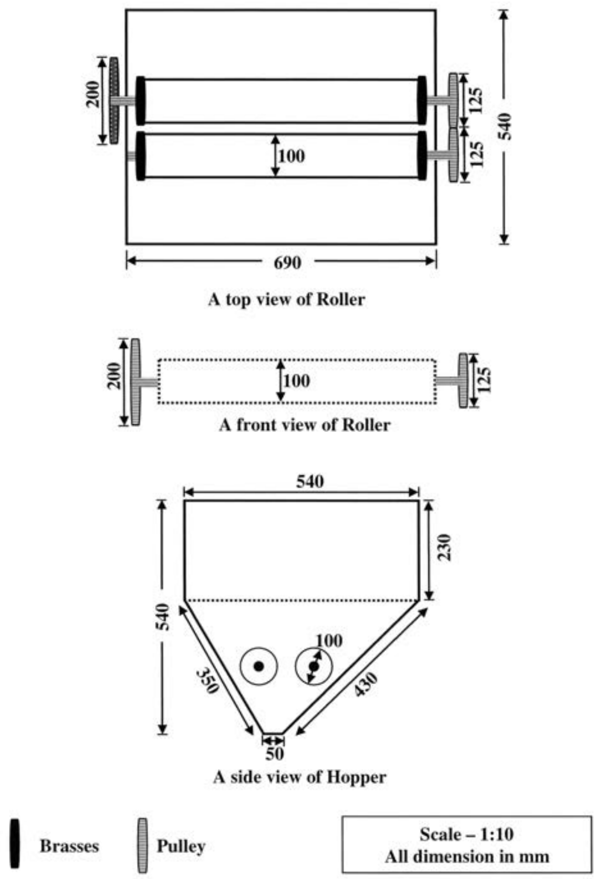


Teeth ratio = 15:1
(Flywheel ring : Pinion)

	Diameter (mm)
Roller gear (2')	125
Flywheel ring (1')	400

Speed (rpm)	Pulley No.	Diameter of Pulley (mm)
1500	1-Driver	100
750	2-Driven	200
750	3-Driver	75
187.5	4-Driven	300
187.5	5-Driver	75
70.3	6-Driven	200

Fig. 2 View of roller and hopper



ping through the sieve. Similarly, if the worms had not been affected by shaking and it would have remained straight, the hole of the sieve would have been circular in shape with size of the opening less than the mean length of worms selected randomly in order to prevent dropping of worms with the compost. A view of worm behaviour study is shown in **Fig. 3**.

Hypothesis Generation

It is a fact that the sieving must be accompanied by the shaking process. The popular technique of shaking is either to provide a rider on the rail or to insert a cam to provide necessary jerk. Both principles were not undertaken, because in case of riders, there were all possibilities of dropping of worm and compost out of sieve due to excessive jumping and bumping. Similarly, provision of cam arrangement would have raised the cost of manufacturing making the machine expensive. Thus, Disproportionate weight theory was generated to provide sufficient jerk in each cycle of reciprocation.

Disproportionate weight theory: causes jerk due to imbalance of weight (force analysis)

1) For pushing action of the sieve

Assumptions:

w = Weight of the sieve

w′ = Weight of the compost dispersed over the sieve

θ = Angle of connecting rod with horizontal

FBD of the Rear End of the Sieve

∑V = Total vertical downward

Weight on the rear portion of the sieve during pushing action

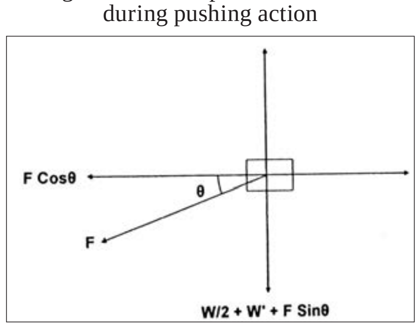
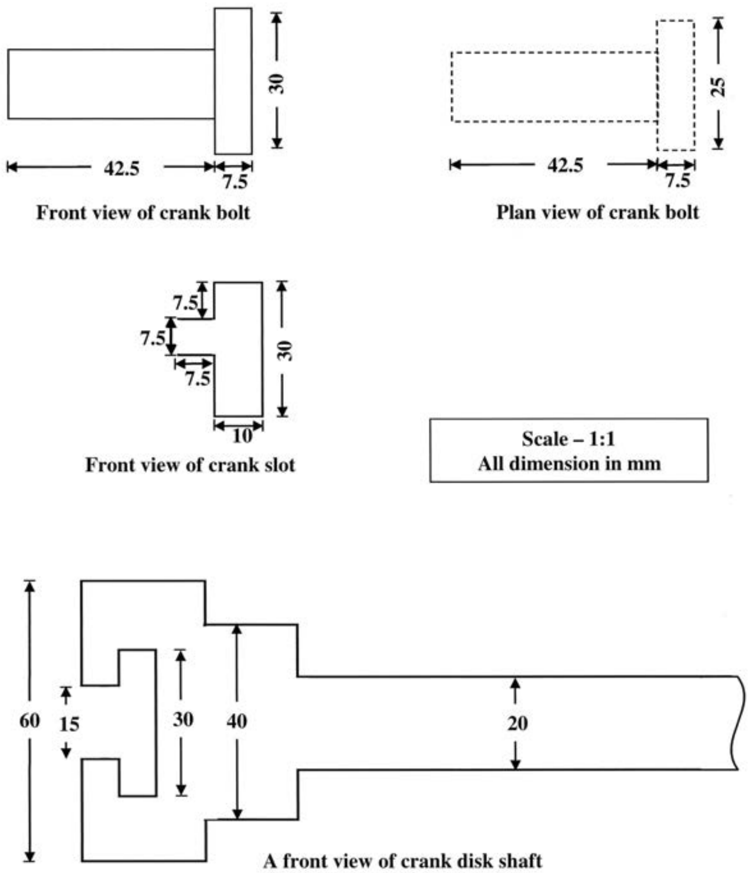


Fig. 1 View of cranks



Details of sieves and collecting pan

Sieve No.	Hole dia (mm)
1.	6
2.	3

Collecting pan was made from metal sheet of 22 gauge and without any hole.

force at the rear portion of the sieve

$V_1 = W/2 + W' + F \sin\theta$ .... (1)

During pushing action, compost spreads only at front half portion of sieve.

FBD of the Front Portion of the Sieve

$\sum V$ = Total vertical downward force at the front portion of the sieve

$\sum V = V_2 = W/2 + F \sin\theta$ .... (2)

D_1 = Difference in weight at the rear and front portion of the sieve during pushing action

$= V_1 - V_2 = W'$

For pulling action of the sieve

Assumption:

W = Total weight of the sieve

W'' = Spread mass of the compost on rear portion of the sieve

W''' = Spread mass of the compost on front portion of the sieve

FBD of the rear portion of the sieve

$\sum V$ = Total vertical downward force at the rear portion of the sieve (V_3)

$\sum V = V_3 = w/2 + W'' - F \sin\theta$

FBD of the front portion of the sieve

$\sum V$ = Total vertical downward force at the front portion of the sieve (V_4)

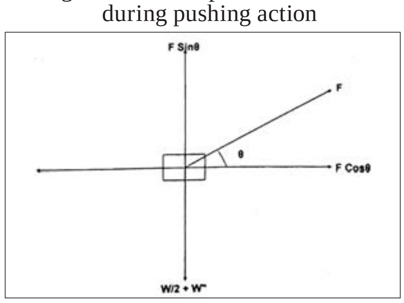
$\sum V = V_4 = w/2 + W''' - F \sin\theta$

D_2 = Difference in force at the rear portion and the front portion of the sieve $= V_3 - V_4 = W'' - W'''$

Since, $D_1 > D_2$,

This difference in weight causes imbalance during push and pull and thus creates shaking action while pulling the sieve in every reciprocating cycle.

Weight on the rear portion of the sieve during pushing action



Selection of Materials

Selection of material is a vital component for development of any machine. It was decided to select the desired size and specifications of pulley, shaft, angle iron, G.I. sheet, belt, bearings etc. from market as engineering drawing of the machine are given in **Figs. 1**, **2**, and **3**. Hopper, roller, frame etc. were fabricated as per design. The details of machine parts are given in **Table 1**.

Design and Development

After selection of various components, the design of hopper and roller was undertaken.

Design of the Hopper: The hopper was designed for sufficient space to accommodate enough compost and capable to supply compost on sieve continuously without any clogging.

Thus, a trapezoidal shaped hopper with vertical edge was considered. As the angle of repose of compost lies between the ranges of 22-30 degree at 15 % moisture the side slope of hopper was kept at 40 degree.

Base of the hopper was provided with 50mm wider opening with full length of the hopper so as to ensure maximum compost discharge. Two wooden rollers were provided inside

Table 1 Specification of machine parts

Components		Specification
(a) Frame	Material	Angle iron (1.5″ × 1.5″)
	Dimension	41″ × 33″ × 54″
(b) Roller	Material	Wood wrapped with fibrous rubber roll
	Dimension	
	Length	26″
	Diameter	4″
(c) Shield bearing	Size	6″
	Number	04
(d) Spur-gear	Number	02
	Diameter	5″
	No. of teeth	40
	Circular pitch	10 mm
(e) Hopper	Material	Mild steel
	Dimension	27″ ×21″ ×21″
(f) Fly wheel	Material	Cast iron
	Diameter	16″
	Weight	17 kg
	No. of teeth	135
	Circular pitch	10 mm
	Dedendum+Addendum	7 mm
	Fly wheel toothed ring	9 teeth
(g) Sieve Material Mild steel		
	Amplitude of sieving	Adjustable through cam arrangement
	Upper sieve	
	Hole Diameter	6 mm
	Lower sieve	
	Hole Diameter	3 mm
(h) Pulley	Material	Cast iron
	Number	03
	Size	8″ & 12″
	Groove angle	45°
(i) Bearing	Number	08
	Bearing number	6206, 6205
(j) Motor	Power	2 hp (Single Phase) 1500 rpm
(k) Cam	Material	Steel
	Diameter or rotor	60 mm
	Length of cam shaft	250 mm
	Slot dimension	
	Length	250 mm
	Width	17.5 mm
	Groove width	10 mm

the hopper to facilitate the sieving process by breaking the clods. The discharge control lever controlled discharge of compost from the hopper. Hopper depth was kept as 540 (ie 310 + 230) mm upto bottom. The upper width of hopper was kept 540 mm.

Calculation of operating volume of the hopper:

The area of the hopper cross-section

= volume of trapezoidal section+ volume of rectangular section

$= [1/2 \times (50 + 540) \times 310] + 540 \times 230$

$= 215650\ mm^2$

Therefore, volume of hopper

$= 215050 \times 690\ mm^3$

$= 14.87 \times 10^{-2}\ m^3$

Calculation of Compost Weight

Particulars of compost

Moisture content = 15 %

Bulk density = 666 kg/m^3

Therefore, the weight of compost accommodated in 2/3rd of the hopper. (Hopper is supposed to be filled not more than 2/3rd of total volume)

$= 2/3 \times (14.87 \times 10^{-2}) \times 666 = 66\ kg$

Hence, the designed dimensions of hopper are as follows:

Volume of the hopper = $14.87 \times 10^{-2}\ m^3$

Side slope of hopper = *40 degree*

Area of hopper cross-section = $15.9 \times 10^{-2}\ m^2$

Length × width × height = *690 mm × 540 mm × 540 mm*

Design of the Roller

Two wooden cylindrical rollers of 100 mm diameter and 650 mm length rotating in the horizontal plane just above the hopper bottom opening were considered for uniform flow of compost under gravity. The rollers were wrapped with fibrous rubber to facilitate the breaking of compost clods without any damage to the worm. The end of the roller was associated with the metal braces to provide enough support to it while working. The spur gears used to drive roller regulated their revolution in opposite direction.

Speed of the roller:

Roller is getting power from pulley no. 5 with 75 mm diameter. Speed of pulley no. 5 (N_5) is 187.5 rpm; and Pulley no. 6 having diameter 200 mm is being powered by pulley no. 5.

Therefore,

Velocity of pulley no. 5 = Velocity of pulley no. 6

$\pi D_5 N_5 - \pi D_6 N_6$

$N_6 = D_5 / D_6 \times N_5 = (75 \times 187.5) / 200 = 70.3\ rpm \cong 70\ rpm$

Energy stored in the roller when it is idle motion $= 1/2 \times I\omega^2 = 1/2 \times MR^2 \times \omega^2$

Mass of the roller = 5 kg; Mass of fibrous sheet = 0.5 kg; Radius of the roller = 50 mm

Total mass (roller + fibrous rubber) = 5.5 kg

Angular speed (ω) = $(2\pi N / 60)\ 7.33$ rad/s

Energy = $1/2 \times 5.5 \times (50 \times 10^{-3})^2 \times (7.33)^2 = 0.37$ Joule

So, the energy (per sec) required by roller for rotation

E = $2 \times 0.37 = 0.74 = 9.9 \times 10^{-4}$ hp

Power for sieving:

Machine was designed for running both manually (with handle) and with an electric motor. Thus, it was necessary to assess the capacity of motor to be fitted in the machine. Accordingly, the power assessment was made with assumptions.

1. Hopper is supposed to be filled not more than 2/3 rd of total volume.
2. Maximum hopper capacity (weight of the compost) is taken for calculation of power requirement considering instantaneous deposition over first sieve.

The connecting rod rotates with angular velocity of ω rad/s and the crank turns through an angle θ from the inner dead centre. Let X be the displacement of a reciprocating body P (multi-layer sieve) from I.D.C. after time t seconds, during which the crank has turned through an angle θ (**Fig. 4**).

Let l = length of connecting rod between the centers,

r = radius of crank

φ = Inclination of connecting rod to the line of stroke PO

n= Ratio of length of connecting rod to the radius of cam = 1/r

Velocity of the Reciprocating Body P (Multi-Layer Sieve)

$X = P'P = OP' - OP = (P'C' + C'O) - (PQ + QO)$

$= (l + r) - (lCos\varphi + rCos\theta)$

$= r(1 - Cos\theta) + l\ (1 - Cos\varphi)$

$= r\ [(1 - Cos\theta) + l/r\ (1 - Cos\varphi)]$

$= r\ [(1 - Cos\theta) + n\ (1 - Cos\varphi)]$

From ΔCPQ and ΔCQO,

$CQ = lSin\varphi = rSin\theta$ or,

$l/r = Sin\theta / Sin\varphi$

$n = Sin\theta / Sin\varphi$ or, $Sin\varphi = Sin\theta / n$

$Cos\ \varphi = (1 - Sin^2\varphi)^{1/2} = [1 - (Sin^2\theta / n^2)]^{1/2}$

$Cos\varphi = 1 - 1/2 \times (Sin^2\theta / n^2) + ...$ or,

$1 - Cos\varphi = Sin^2\theta / 2n^2$

$X = r\ [(1 - Cos\varphi) + n \times (Sin^2\theta / 2n^2)]$

$dx / d\theta = r\ [Sin\theta + (1/2n) \times 2Sin\theta\ Cos\theta]$

$= r\ [Sin\theta + (Sin2\theta / 2n)]$

Therefore, velocity of P with respect to O

$V_{po} = V_p = dx/dt = dx/d\theta \times d\theta/dt = dx/d\theta \times \omega$

$V_{po} = V_p = \omega r\ [Sin\theta + (Sin2\theta / 2n)]$

Acceleration of the Reciprocating Body P

Acceleration is the rate of change of velocity, therefore acceleration of the cam P

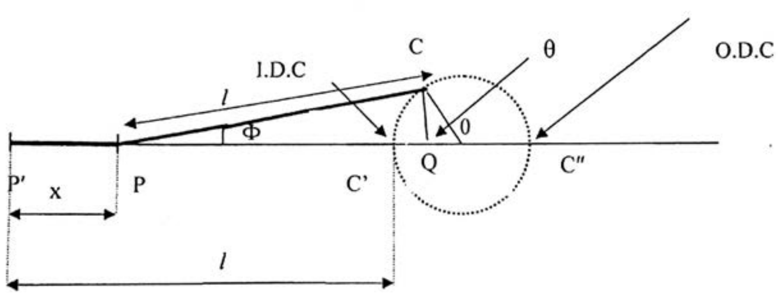
$a_p = dv_p/dt = dv_p/d\theta \times d\theta/dt = \omega \times dv_p/d\theta$

Differentiating both sides

$dv_p/d\theta = \omega r\ [Cos\theta + (2 \times Cos2\theta)/2n]$

$a_p = \omega^2 r\ [Cos\theta + (Cos2\theta/ n)]$

Fig. 4 Motion of a crank and connecting rod.



We are designing for the maximum acceleration and velocity of the cam bolt. So,

$a_p\ (max.) = \omega^2 r\ (1 + 1/n)$

at $\theta = 0^o$

$V_p\ (max.) = \omega r\ (1 + 0)$

at $\theta = 90^o$

Power consumed by reciprocating shaft and sieve in sieving. Assume 66 kg (maximum hopper capacity)

Radius of crank rotation = 30 mm;

Length of connecting rod = 250 mm

Speed of crank (rpm) = 187.5;

Weight of sieve = 39.49 kg

Total mass of the reciprocating part (sieve + compost) m = $(66 + 39.49)$ kg = 105.44 kg

Power required for sieving = $(ma_p) \times V_p$

$= m\omega^2 r\ (1 + 1/n) \times \omega \times r$

$= m \times (2\pi N)^2 \times r \times (1 + r/l) \times (2\pi N) \times r$

$= 105.44 \times [2 \times \pi \times 187.5/60]^2 \times 0.03 \times (1 + 0.03/0.25) \times (2\pi \times 187.5/60) \times 0.03$

$= 804.55$ w

$= 1.07$ hp

Power requirement after considering the transmission losses (25 %) as frictional loss and slippage loss, between pulley drive, eccentric arrangement for reciprocating motion, gear etc.

$= 1.07 + 1.07 \times 50.25 = 1.35$ hp

Limit of safe design power = calculated motor capacity + 40 % of calculated power taken as factor of safety + energy (per sec.) required by rollers for rotation

$= 1.35 + 1.35 \times 0.4 + 9.9 \times 10^{-4} = 1.89$ hp

Motor of 1.89 hp capacity is not available in the market, therefore a motor of little higher capacity i.e. 2 hp was procured.

This section can be reduced considerably by omitting the mathematical development of equations since these equations are very elementary slider-crank mechanisms given in second year engineering texts.

Power Cycle and Speed Ratio

For optimum compost production, rpm of flywheel was kept 50, which

Table 2 Compost production capacity of machine vis-à-vis conventional method

Observations	Running time (minute)	Conventional		Mechanical sieving			
				Motorized		Manual	
				at 15-22 % moisture content			
		Discharge (kg)	Discharge Capacity (q/h)	Discharge (kg)	Discharge Capacity (q/h)	Discharge (kg)	Discharge Capacity (q/h)
O_1	15	16.75	0.67	190	7.60	90	3.60
O_2	15	13.00	0.52	180	7.20	90	3.54
O_3	15	15.75	0.63	185	7.40	87	3.50
O_4	15	12.50	0.50	178	7.10	90	3.62
O_5	15	11.25	0.45	188	7.52	89	3.58
Average discharge capacity			**0.56**		**7.40**		**3.60**

Table 3 Worm sieving efficiency of conventional method (By number)

Observation	Compost (kg)	Worm separated	Dropping from sieve	Mortality	Efficiency (%)
O_1	20	377	20 (5.03)	0	94.97
O_2	20	362	23 (6.00)	1 (0.25)	93.75
O_3	20	301	24 (7.34)	2 (0.61)	92.05
O_4	20	371	23 (5.80)	0	94.20
O_5	20	359	27 (7.00)	1 (0.36)	92.64
				Average	**93.52**

Figures in parentheses indicated the percentage

Table 4 Worm sieving efficiency of machine under manual and motorized operation

Observation	Compost (kg)	Worm separated	Dropping from 1st sieve	Dropping from 2nd sieve	Mortality	Efficiency (%)
Manual operation						
O_1	15	280	13 (4.30)	2 (0.60)	1 (0.33)	94.8
O_2	15	267	11 (3.90)	1 (0.35)	1 (0.35)	95.4
O_3	15	286	08 (2.70)	0 (0.00)	2 (0.67)	96.6
O_4	15	274	11 (3.80)	1 (0.35)	0 (0.00)	96.1
O_5	15	279	09 (3.10)	0 (0.00)	0 (0.00)	96.9
					Average	**95.9 ≈ 96.0**
Motorized operation						
O_1	15	285	5 (1.70)	0 (1.70)	1	98.20
O_2	15	271	7 (2.50)	0 (1.70)	0	97.50
O_3	15	286	4 (1.40)	2 (1.70)	0	97.90
O_4	15	277	4 (1.40)	2 (1.70)	0	97.9
O_5	15	281	5 (1.70)	1 (1.70)	0	97.95
					Average	**97.9 ≈ 98**

Figures in parentheses indicate the percentage

is accessible by motorized operation as well as manual operation with handle. Accordingly, 1500 rpm of motor needs to be reduced upto 50 rpm at flywheel by selecting suitable size of pulleys and belts.

Machine Installation:

After procurement of motor of desired power, gears and pinions of requisite teeth number, belts of desired specification etc. fabrication of hopper, roller, sieve, channels etc. was completed. The machine was installed properly for testing as per drawing (**Fig. 1**).

Prototype testing:

On and off farm testing of prototype was done with sufficient amount of vermi-compost. The observations were taken with respect to output capacity, worm mortality, sieving efficiency and economics of compost production under manual and motorized operation of machines in order to analyze the data. A view of manually operation of machine with handle and view representing evaluation of compost quality by Vice-chancellor, RAU, Pusa is shown in **Figs. 4** and **5**.

Table 5 Comparative economics of compost production by machine vis-a-vis conventional method

Machine	Fixed cost US $/tonne	Operating cost US $/tonne	Total cost US $/tonne	Benefit/ quintal over conventional method US $/tonne
Motorized	0.05	0.50	0.55	7.73
Manual	0.10	1.31	1.41	6.87
Conventional	8.27	0.01	8.28	-

Results and Discussion

The observed data on compost production capacity, worm mortality rate, sieving efficiency and economics of the compost production have been presented in **Tables 2** to **5**.

It is found from **Table 2** that the compost production was maximum (7.4 q/h) by motorized operation of machine followed by 3.6 q/h with manual operation through handle. Under conventional method, i.e. sieving through wire-net sieve by two persons, capacity was found to be 0.56 q/h only. Similarly, machine had maximum sieving efficiency (98 %) under motorized operation followed by 96 % while operated with handle and the efficiency was minimum (93.5 %) in case of conventional method of sieving. This is due to reciprocating speed of the sieves, where worms get less time to pass through first sieve mainly employed for worm separation, and they roll out of the sieve safely. Under conventional method, reciprocating motion to sieve is provided by hands and worms get minimum displacement in each cycle, providing them more time to pass through net-hole (**Tables 3** and **4**).

The economics of compost production was evaluated on the basis of cost of compost preparation. The loss due to dropped or damaged worm was not taken into account in all cases being it almost negligible. From perusal of data for benefit under machine operation over conventional method, it was found that there was a gain of US$ 7.73 per tonne compost sieving under motorized operation followed by US$ 6.87 per tonne under manual operation of

Fig. 2 A view of fabricated worm sieving machine

Fig. 3 A view of work behaviour study

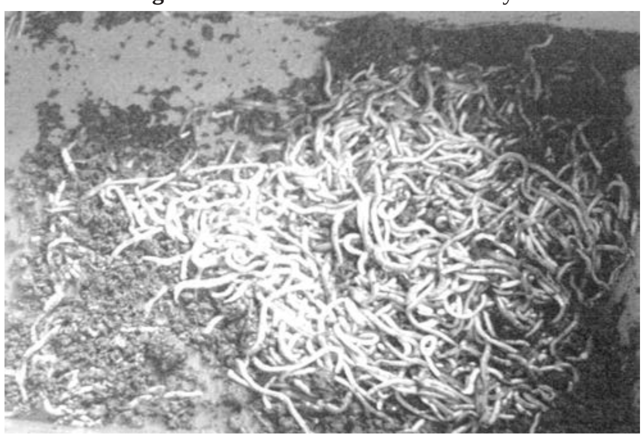


Fig. 4 A view of manually operation of machine with handle

Fig. 5 View representing evaluation of compost quality by Vice-chancellor, RAU, Pusa

machine (**Table 5**).

Conclusions and Recommendations

1. It is concluded from the study that the motorized operation of machine gave maximum output with maximum sieving efficiency followed by its manual operation with handle.
2. The hourly benefit of use of machine clearly demonstrates a significant difference in saving of cost of production of compost when sieving is done by machine run by motor followed by its manual operation with handle. However, high capacity of machine under motorized operation justifies its use for commercially utilized compost units.
3. The machine operation with handle appears to be most useful for medium farmers as well as small commercial compost producers, who do not have much capital to invest for mechanization process. Moreover, the low output capacity of machine under its manual operation would provide a larger use period, ultimately reducing the cost of operation due to reduction in fixed cost.

It is recommended to go for the commercial production of vermicompost by this machine (manually operated and motorized). But for the farmers having small compost units, the use of manually operated machine will be better to make the final product cost effective.

REFERENCES

Stevenson, W. A. 1980. Worm-harvester. United States Patent 4187946. http://www.freep [atentonline.com/4187946..html

Slobodian, H. 1999. Worm-harvester. United States Patent 5884579. http://www.freep [atentonline.com/5884579..html

Curro, S. J. 2003. Method and device for harvesting earthworms. United States Patent 6618977. http://www.freep[atentonline.com/6618977.html

Optical and Electrical Properties for Determining the Optimal Harvest Time of Green Beans and Green Peas Pods Using Visible Laser

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Abstract

The main objectives of this research was to use visible laser for determine the optimal harvest time of green beans (*Phaseolus vulgaris L. var Paulista*) and Sweet pea's (*Pisum Sativum L. var Sugar Lays*) with its optical and electrical properties at different ages. The obtained results are summarized as follow: 1) The values of light reflection intensity were increased by using He-Ne laser (wavelength 632.8 nm) from 15 to 59 Lux for ages of green bean pods from 10 to 31 days, respectively, meanwhile these values were decreased by using He-Ne laser (wavelength 543.5 nm) from 46 to 10 Lux; 2) The values of light reflection intensity were increased by using He-Ne laser (wavelength 632.8 nm) from 10 to 39 Lux for ages of green peas pods from 6 to 33 days, respectively, meanwhile these values were decreased by using He-Ne laser (wavelength 543.5 nm) from 35 to 9 Lux; 3) The values of electrical signals were increased by using He-Ne laser (wavelength 632.8 nm) and decreased by using He-Ne laser (wavelength 543.5 nm) for ages of green pean and pea pods.; and 4) There were relationships between intensity of light and electrical reflections by using two He-Ne laser as a function of the green beans and pea pod's age. And the He-Ne laser with wavelength 632.8 nm is suitable laser results high reflection from green bean and sweet pea pods at ages 22 and 18 days, respectively (optimal harvest time) from the appearance of the flowers pods.

Introduction

If a laser beam is directed at a tissue (living surface), it may be reflected back to the source or to another undesired surface. If reflectance is adequately controlled and the light enters the tissue, the ultimate event affecting the tissue is absorption of the light. However, the tissue itself can scatter the light. Alternatively, the light might be transmitted right through the tissue with only a minimal amount being absorbed; since every tissue has reflective, scattering and transmission properties (Ahn and Moore, 1992).

Slaughter (1995) investigated a non-destructive optical method for determining the internal quality of intact peaches and nectarines. The method, based upon visible and near-infrared spectrophotometric techniques, was capable of simultaneously predicting the soluble solids content, sucrose content, sorbitol content, and chlorophyll A content of intact peaches and nectarines, and required no sample preparation. The visible and NIR-spectroscopy could be used to measure non-destructively the internal quality of peaches and nectarines.

Salunkhe and Kadam (1998) stated that the harvest time is determined largely by the appearance of the pods. These should be well filled with tender young peas and changing in color from dark to light green. The harvest should be made when the peas are still in prime condition, but without sacrificing the yield.

Zur et al. (2000) suggested normalization of the leaf absorbance spectra (A_λ) to the red Chl absorbance at 678 nm (A_{678}). They stated that the reflectance around 520 nm correlates closely with carotenoids content in yellow to green leaves. Thus, this spectral feature at 520 nm could be used as a measure of carotenoids content in green leaves and plant.

Hassan (2002) showed that the optical properties were determined for the soundness and blemishes of oranges using helium-Neon (He-Ne) with wavelength 632.8 nm and Argon laser with wavelengths of 514, 496 and 488 nm, respectively and power of 10 mW. The He-Ne laser is suitable to use because it gives high reflection and a criterion to identify defects for each variety of oranges.

Corgan (2004) stated that beans (snap) harvest when full-sized pods, beans about 1/4 of their mature size, before constrictions in the pod are evident. And beans (lima) harvest when well filled, but not over mature. Seeds should be green and tender. But peas (English) harvest when bright green, pods fully developed but still tender, and before seeds develop fully.

Gitelson and Merzlyak (2004) stated that reciprocal reflectance $(R_\lambda)^{-1}$ in the spectral range λ from 520 to 550 nm and from 695 to 705 nm related closely to the total pigment content (chlorophylls + carotenoids) in leaves of all species.

El-Raie et al. (2005) found that reflection intensity using laser beam 632.8 nm was higher than intensity reflection using laser beam 543.5 nm in the stages 3, 4, 5 and 6 of strawberry. There is reverse relation between reflection and absorption percentages, where the reflection increased from stage 1 to 6, while the absorption percentage decreased. By increasing the quantity of optical reflection, the electrical signals increased using laser with wavelength 632.8 nm, because this wavelength was more compatible with color wavelength of mature stages strawberry than 543.5 nm.

Gitelson et al. (2006) suggested a model, using reflectance in three spectral bands has been applied for non-destructive assessment of total chlorophyll, carotenoid and anthocyanin contents in plant leaves. In Anth-free leaves, both the green and the red edge bands can be used as λ_1 for Chl estimation and as λ_2 for Car estimation. Only four spectral bands are required for three pigments retrieval: 510-520 nm (carotenoids), 540-560 nm (anthocyanins), 690-710 nm (total chlorophyll) and 760-800 nm.

The objectives of the present study was to measure and determine the following: 1) Optical and electrical properties of green beans and

Fig. 1 Experimental set up for measuring the intensity of light (A) and electrical (B) reflections from the pods using visible laser

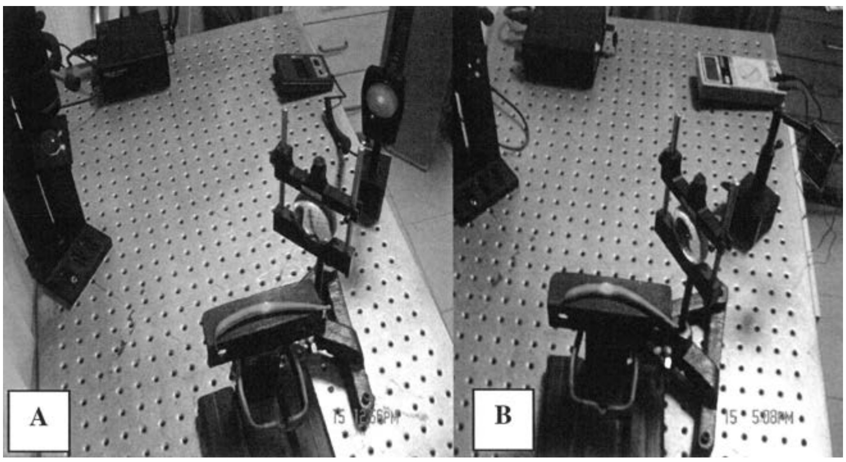
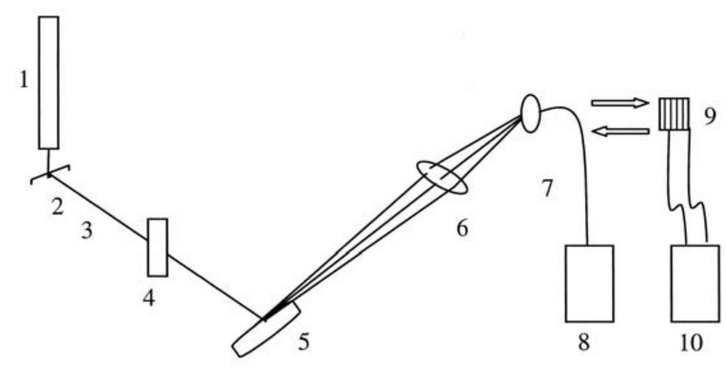


Fig. 2 The assembled setup for light and electrical reflections



1: Laser source; 2: Mirror; 3: Laser beam; 4: Filter; 4: Filter; 5: Sample; 6: Convex lens; 7: Detector; 8: Lux meter; 9: Photovoltaic cell; 10: Avo meter.

peas pods at different ages using visible laser, 2) Predicting regression equation to express the relationships between two reflections using two different wavelengths, 3) Suitable wavelength to determine the optimal harvest time of pods, and 4) Establish a criterion to identify optical and electrical properties of pods for sorting and grading using visible laser.

Table 1 The intensity of reflection (Lux) from green bean pods at different ages using He-Ne laser with two wavelengths

Pod's age, day	He-Ne laser					
	wavelength 632.8 nm			wavelength 543.5 nm		
	Range, Lux	Mean value, Lux	Mean intensity of reflections, Lux	Range, Lux	Mean value, Lux	Mean intensity of reflections, Lux
10	16-24	20.0	20.0 ± 4.0	27-46	36.5	36.5 ± 9.5
13	15-30	22.5	22.5 ± 7.5	25-45	35.0	35.0 ± 10.0
16	21-36	28.5	28.5 ± 7.5	23-43	33.0	33.0 ± 10.0
19	27-45	36.0	36.0 ± 9.0	20-39	29.5	29.5 ± 9.5
22	30-49	39.5	39.5 ± 9.5	17-36	26.5	26.5 ± 9.5
25	32-51	41.5	41.5 ± 9.5	15-32	23.5	23.5 ± 8.5
28	36-56	46.0	46.0 ± 10.0	13-28	20.5	20.5 ± 7.5
31	38-59	48.5	48.5 ± 10.5	10-26	18.0	18.0 ± 8.0

Material and Methods

The samples of green beans (*Phaseolus vulgaris L. var Paulista*) and sweet pea's or green pea's (*Pisum Sativum L. var Sugar Lays*) pods were obtained from green house of the central laboratory for agricultural climate, Agricultural Research Center (ARC) at Dokki, Giza, ARE.

The Setup for Light and Electrical Reflections:

The experimental setup (**Figs. 1** and **2**) was developed and assembled in the laboratory of laser applications in agricultural engineering, (NILES), Cairo University and consists of laser source, filter, lenses, holders, digital luxmeter, photovoltaic cell, and avometer.

He-Ne lasers: The helium-neon (He-Ne) lasers {Red (05-LHP-151, U.S.A) and Green (05-LGR-173, U.S.A)} in the visible light (wavelengths 632.8 and 543.5 nm) with power 8 and 4 mW, respectively, were used in the present work as light sources.

Filter: The filter (50510, U.S.A) was calibrated metallic neutral density filter will fill a variety of attenuation needed in the Ultra-violt, visible and near infrared. It was position in front of laser beam (He-Ne red) to control its power

Lens: The convex silica glass lens of 100 mm focal length with diameter 75 mm was used. The lens was used with angle 45º to focus the reflected light collected from the pod surface one time onto the luxmeter detector and other onto photovoltaic cell connected with avometer.

Holders: Holders fabricated from copper were used to hold lens, filter, sample, luxmeter detector and photo cell.

Digital luxmeter (Lx-101, Japan) with high accuracy and sensitivity was used to measure the intensity of light reflection from pods surface.

Photovoltaic cell: Photovoltaic cell length 60 mm and width 40 mm. Its efficiency is about 23 %. It was mounted on a holder which allowed the cell to move at any direction. The intensity of the reflected light is transformed to voltage by photovoltaic cell which was transferred to an avometer.

AVO meter (Digital millimeter mod. CDA-701, Japan): was used to measure the electrical signal with volt resulted from converting the reflection of light from pods surface by a photovoltaic cell.

Laboratory Tests:

The intensity of light reflection from pods surfaces was carried out using setup **Fig. 1**. Pods of green beans and sweet peas at different ages exposure to the laser and detector of luxmeter device measure the intensity of light from the pods.

The electrical signal with mille volt was obtained by using setup **Fig. 1**. The AVO meter device received the reflectance light from the pods of green beans and sweet peas at different ages.

The absorption of pods was calculated from the following equation according to the law of conservation of energy:

$I = R + A$ .... (1)

Where: I is the incident beam, lux; R –reflective beam, lux; and A–absorptive beam, lux.

Results and Discussion

Optical Properties:

When light is incident on any material, it may be reflected, transmitted through it, and absorbed within it. The degree to which these phenomena take place depends on the nature of the material, particular wavelength of the electromagnetic spectrum used; and the angle of the incidence. Green beans and sweet pea pods were exposed to helium neon laser with two wavelengths 632.8 and 543.5 nm. The experimental setup was adjusted at incident angle equal to reflected angle (45º) to obtain high reflections.

Green bean pods:

Table 1 illustrates that the values of the intensity of light were increased with He-Ne laser (wavelength 632.8 nm) compared with He-Ne laser (wavelength 543.5 nm). They were ranged from 16 to 24, 15

Table 2 Percentages of reflection and absorption for green bean pods at different ages using He-Ne laser at two wavelengths

Age, Day	He-Ne laser (632.8 nm)			He-Ne laser (543.5 nm)		
	Mean reflection, Lux	Reflection, %	Absorption, %	Mean Reflection, Lux	Reflection, %	Absorption, %
10	20	0.70	99.30	36.5	1.30	98.70
13	22.5	0.78	99.22	35	1.25	98.75
16	28.5	0.99	99.01	33	1.18	98.82
19	36	1.25	98.75	29.5	1.05	98.95
22	39.5	1.37	98.63	26.5	0.95	99.05
25	41.5	1.44	98.56	23.5	0.84	99.16
28	46	1.60	98.40	20.5	0.73	99.27
31	48.5	1.69	98.31	18	0.64	99.36

Table 3 The intensity of reflection (Lux) from sweet pea pods at different ages using He-Ne laser with two wavelengths

Pod's age, day	He-Ne laser					
	wavelength 632.8 nm			wavelength 543.5 nm		
	Range, Lux	Mean value, Lux	Mean intensity of reflections, Lux	Range, Lux	Mean value, Lux	Mean intensity of reflections, Lux
6	10-16	13.0	13.0 ± 3.0	29-35	32	32 ± 3
9	13-19	16.0	16.0 ± 3.0	24-31	27.5	27.5 ± 3.5
12	15-22	18.5	18.5 ± 3.5	21-29	25	25 ± 4
15	17-26	21.5	21.5 ± 4.5	19-28	23.5	23.5 ± 4.5
18	19-29	24.0	24.0 ± 5.0	16-26	21	21 ± 5
21	22-32	27.0	27.0 ± 5.0	14-25	19.5	19.5 ± 5.5
24	23-35	29.0	29.0 ± 6.0	13-24	18.5	18.5 ± 5.5
27	25-37	31.0	31.0 ± 6.0	11-23	17	17 ± 6
30	26-39	32.5	32.5 ± 6.5	10-23	16.5	16.5 ± 6.5
33	27-39	33.0	33.0 ± 6.0	9-21	15	15 ± 6

to 30, 21 to 36, 27 to 45, 30 to 49, 32 to 51, 36 to 56, and 38 to 59 Lux at pod's ages 10, 13, 16, 19, 22, 25, 28, and 31 days, respectively. However, the values of intensity of light reflection were decreased by using He-Ne laser (wavelength 543.5 nm) compared with the other wavelength (632.8 nm). It is clear that when the ages of pods increase, the intensity of light reflection increased (direct proportion) by using He-Ne laser (wavelength 632.8 nm). However, when the pod's age increases, the intensity of reflection light decreased (converse proportion) by using He-Ne laser (wavelength 543.5 nm).

The ranged values of light intensity of reflections from pods using He-Ne laser (wavelength 632.8 nm) were smaller than the ranged values when using He-Ne laser (wavelength 543.5 nm) at each age. Using the mean values shown in **Table 1**, the following general equations were deduced to express the relationships between intensity of reflection by using laser at wavelength 632.8 nm ($I_{632.8}$) and intensity of reflection by using laser at wavelength 543.5 nm ($I_{543.5}$) of green bean pods at different ages from the appearance of the pods.

For pods at 10 days (first age):

$$I_{632.8} = 1.825\ I_{543.5} \quad (2)$$

For pods at 22 days:

$$I_{632.8} = 0.671\ I_{543.5} \quad (3)$$

For pods at 31 days (last age):

$$I_{632.8} = 0.371\ I_{543.5} \quad (4)$$

Generally, the following equations summarize the relationships between $I_{632.8}$ and $I_{543.5}$ as a function of the pod's age (A).

$$I_{632.8} = 7.213 + 1.388\ A,\quad R^2 = 0.824,\quad F_{Regression} = 3731 \quad (5)$$

$$I_{543.5} = 46.948 - 0.935\ A,\quad R^2 = 0.705,\quad F_{Regression} = 1902 \quad (6)$$

The **Eqns. 5** and **6** indicate that the age affects the intensity of reflection by using laser at wavelength 632.8 nm more than the intensity of reflection by using laser at wavelength 543.5 nm.

Table 2 indicates the percentages of reflection and absorption for green beans pods at different ages using laser at two wavelengths. The percentages of reflection increased, there were 0.70, 0.78, 0.99, 1.25, 1.37, 1.44, 1.60 and 1.69 % but the percentages of absorption decreased into 99.30, 99.22, 99.01, 98.75, 98.63, 98.56, 98.4 and 98.31 % at green bean pod's ages 10, 13, 16, 19, 22, 25, 28 and 31 days age, respectively when wavelength 632.8 nm was used.

Fig. 3 shows a converse relationship between reflection and absorption at different ages of green beans. The light absorption is very higher than the light reflection. It is noticed that reflection increased but absorption decreased from 10 to 31 days old by using He-Ne laser with wavelength 632.8 nm.

By using He-Ne laser with wavelength 543.5 nm (**Fig. 4**), the reflection percentages of green bean pods decreased gradually across pod's ages. The percentages of reflection were 1.3, 1.25, 1.18, 1.05, 0.95, 0.84, 0.73 and 0.64 %. The absorption percentages increased gradually. The percentages of absorption were 98.70, 98.75, 98.82, 98.95, 99.05, 99.16, 99.27 and 99.36 % at pod's ages 10, 13, 16, 19, 22, 25, 28 and 31 days old, respectively.

Sweet pea pods:

Table 3 indicates the range values of the light intensity of sweet pea pods using He-Ne at 632.8 nm increased from: 10 to 16, 13 to 19, 15 to 22, 17 to 26, 19 to 29, 22 to 32, 23 to 35, 25 to 37, 26 to 39 and 27 to 39 Lux at pods ages 6, 9, 12, 15, 18, 21, 24, 27, 30 and 33 days, respectively.

But, the range values of the intensity of light that decreased from 29 to 35, 24 to 31, 21 to 29, 19 to 28, 16 to 26, 14 to 25, 13 to 24, 11 to 23, 10 to 23 and 9 to 21 Lux at pods ages 6, 9, 12, 15, 18, 21, 24, 27, 30 and 33 days, respectively by using He-Ne laser at 543.5 nm.

It is noticed that, when the age of pods increased, the intensity of light reflection increased (direct proportion) by using He-Ne laser (wavelength 632.8 nm). When the pod's age increased, the intensity decreased (converse proportion) by using He-Ne laser (wavelength 543.5 nm).

The ranged values of light intensity of reflections using He-Ne laser (wavelength 632.8 nm) were smaller than the ranged values of light intensity of reflections using He-Ne laser (wavelength 543.5 nm).

Fig. 3 Reflection and absorption percentages of green beans using He-Ne laser 632.8nm

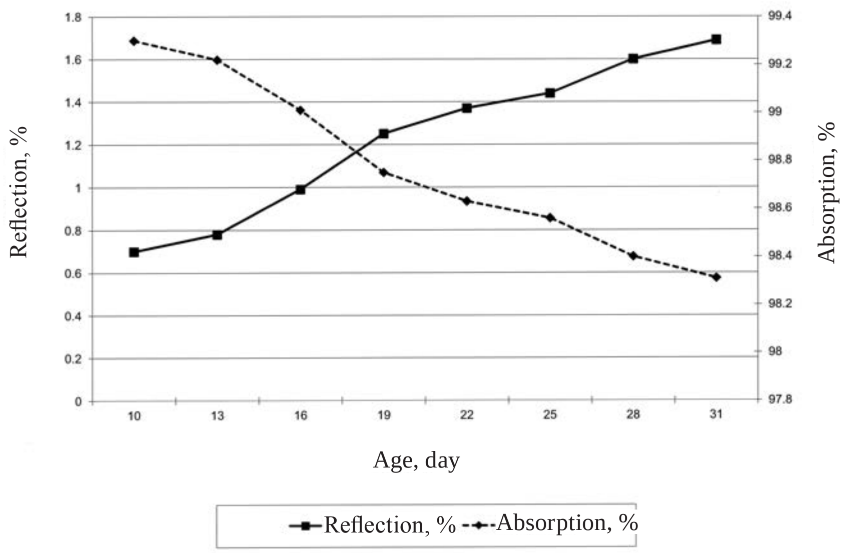
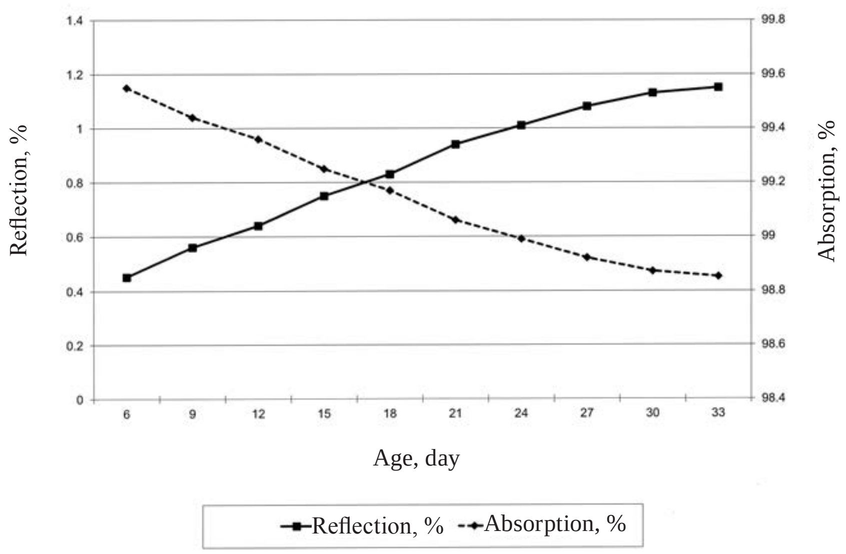


Fig. 4 Reflection and absorption percentages of green beans using He-Ne laser 543.5nm



Using the mean values shown in **Table 3**, the following general equations were deduced to express the relationships between intensity of reflection by using laser at wavelength 632.8 nm ($I_{632.8}$) and intensity of reflection by using laser at wavelength 543.5 nm ($I_{543.5}$) for sweet peas pods at different ages from the appearance of the pods.

For pods at 6 days (first age):

$I_{632.8} = 2.462\, I_{543.5}$ ....(7)

For pods at 18 days:

$I_{632.8} = 0.875\, I_{543.5}$ ....(8)

For pods at 33 days (last age):

$I_{632.8} = 0.455\, I_{543.5}$ ....(9)

Generally, the following equations summarize the relationships between I632.8 and I543.5 as a function of the pod's age (A).

$I_{632.8} = 9.661 + 0.762\, A$,

$R^2 = 0.863$,

$F_{Regression} = 6301$ .... (10)

$I_{543.5} = 32.770 - 0.570\, A$,

$R^2 = 0.759$,

$F_{Regression} = 3151$.................... (11)

The **Eqns. 10** and **11** indicate that: the age affects the intensity of reflection by using laser at wavelength 632.8 nm more than the intensity of reflection by using laser at wavelength 543.5 nm.

Table 4 and **Figs. 5** and **6** show the relation between reflection and absorption at different ages of green peas. It is noticed that reflection increased but absorption decreased from 6 to 33 days age by using laser wavelength 632.8 nm. However, it was the reverse trend when using laser wavelength 543.5 nm.

For both green bean and sweet pea pods, when the age of pods increased, the intensity of reflection light increased by using laser at wavelength 632.8 nm but it decreased when used laser at wavelength 543.5 nm. This means that, at the first ages from the appearance of the pods from their flowers, the values of laser light reflection were higher than the values at last ages at wavelength 543.5 nm, while those

Table 4 Percentages of reflection and absorption for sweet peas pods at different ages using He-Ne laser at two wavelengths

Pods age, day	He-Ne laser (632.8 nm)			He-Ne laser (543.5 nm)		
	Mean reflection, Lux	Reflection, %	Absorption, %	Mean Reflection, Lux	Reflection, %	Absorption, %
6	13	0.45	99.55	32	1.14	98.96
9	16	0.56	99.44	27.5	0.98	99.02
12	18.5	0.64	99.36	25	0.89	99.11
15	21.5	0.75	99.25	23.5	0.84	99.16
18	24	0.83	99.17	21	0.75	99.25
21	27	0.94	99.06	19.5	0.7	99.3
24	29	1.01	98.99	18.5	0.66	99.34
27	31	1.08	98.92	17	0.61	99.39
30	32.5	1.13	98.87	16.5	0.59	99.41
33	33	1.15	98.85	15	0.54	99.46

Fig. 5 Reflection and absorption percentages of sweet peas using He-Ne laser 632.8nm

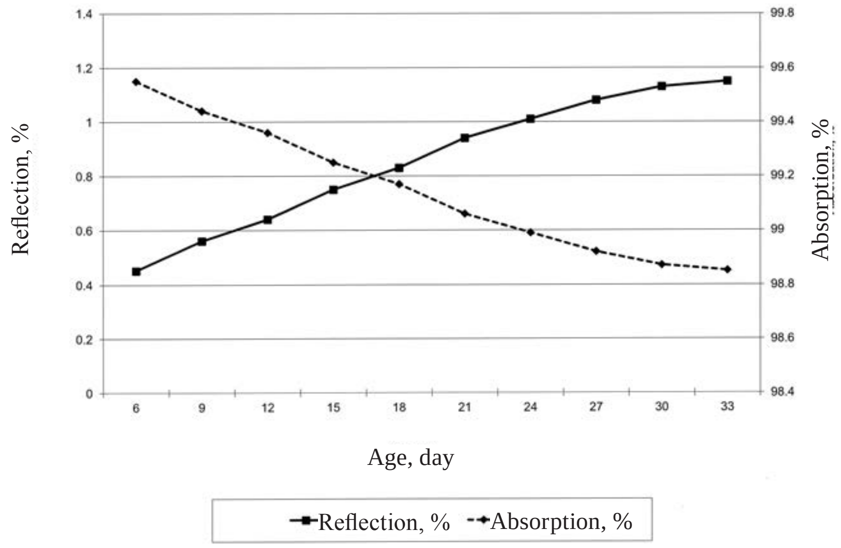
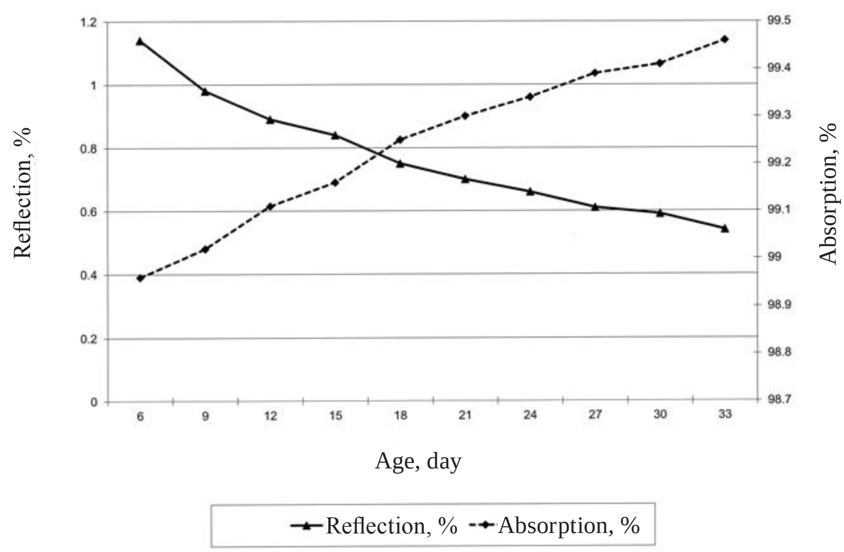


Fig. 6 Reflection and absorption percentages of sweet peas using He-Ne laser 543.5nm



values were smaller than the values at the last ages from the appearance of the flowers pods at wavelength 632.8 nm for both pods of green beans and sweet peas. As the laser beam at wavelength 543.5 nm is a green color, it gave high reflection with the same color (green pods). Thus, the component of green color was the highest at the first ages of the pods then decreased gradually towards the last ages of the pods. So the He-Ne laser with wavelength 632.8 nm is the suitable laser results high reflection from green bean and sweet pea pods at ages 22 and 18 days, respectively (optimal harvest time) from the appearance of the flowers pods.

Electrical Reflection:

The values of measured electrical signals from reflection laser beam (He-Ne laser with two wavelengths) of green pods using electrical photocells (light reflection converted into electrical signal). Generally, when the age of pods (for green beans or sweet peas) increased, the values of the electrical reflection increased with laser wavelength 632.8 nm, but decreased with wavelength 543.5 nm.

Green Bean Pods:

The values of measured electrical signals from reflection of laser beam for pods of green beans were tabulated in **Table 5**. It is noticed that the values of electrical signals from reflection of He-Ne laser (wavelength 632.8 nm) ranged from (30-44), (39-53), (41-63), (40-72), (42-76), (46-82), (52-88), and (55-95) mV at pod's ages 10, 13, 16, 19, 22, 25, 28, and 31 days, respectively. Using laser at wavelength 543.5 nm, the values were ranged from (10.6-20.5), (9.9-19.9), (9.2-19), (8.5-18.7), (7.6-18.2), (6.4-17.8), (5.3-16.5), and (3.8-13.3) mV at ages 10, 13, 16, 19, 22, 25, 28, and 31 days, respectively.

Using the mean values shown in **Table 5**, the following general equations were deduced to express the relationships between electri-

Table 5 The electrical reflection (mV) from green bean pods at different ages using He-Ne laser with two wavelengths

Pod's age, day	He-Ne laser					
	wavelength 632.8 nm			wavelength 543.5nm		
	Range, mV	Mean value, mV	Mean electrical reflections, mV	Range, mV	Mean value, mV	Mean electrical reflections, mV
10	30-44	37	37 ± 7	10.6-20.5	15.55	15.55 ± 4.95
13	39-53	46	46 ± 7	9.9-19.9	14.9	14.9 ± 5
16	41-63	52	52 ± 11	9.2-19	14.1	14.1 ± 4.9
19	40-72	56	56 ± 16	8.5-18.7	13.6	13.6 ± 5.1
22	42-76	59	59 ± 17	7.6-18.2	12.9	12.9 ± 5.3
25	46-82	64	64 ± 18	6.4-17.8	12.1	12.1 ± 5.7
28	52-88	70	70 ± 18	5.3-16.5	10.9	10.9 ± 5.6
31	55-95	75	75 ± 20	3.8-13.3	8.55	8.55 ± 4.75

Fig. 7 Comparison between electrical signal reflections for two wavelengths from green bean pods at different ages

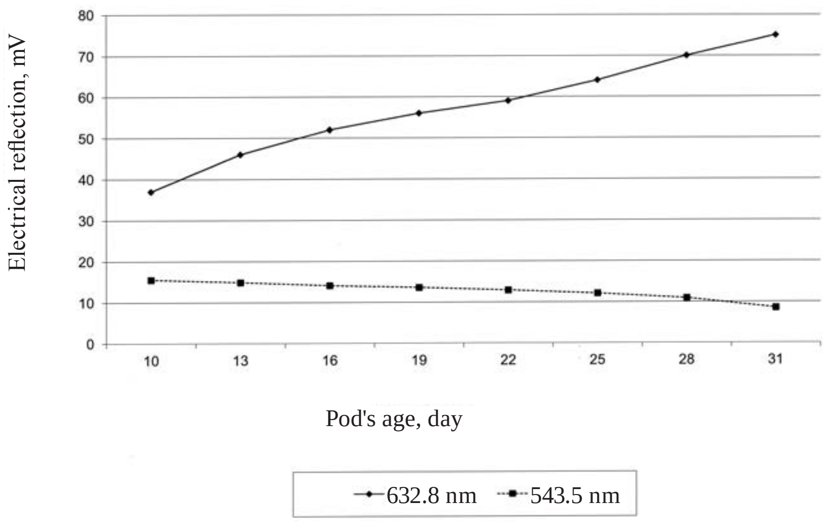
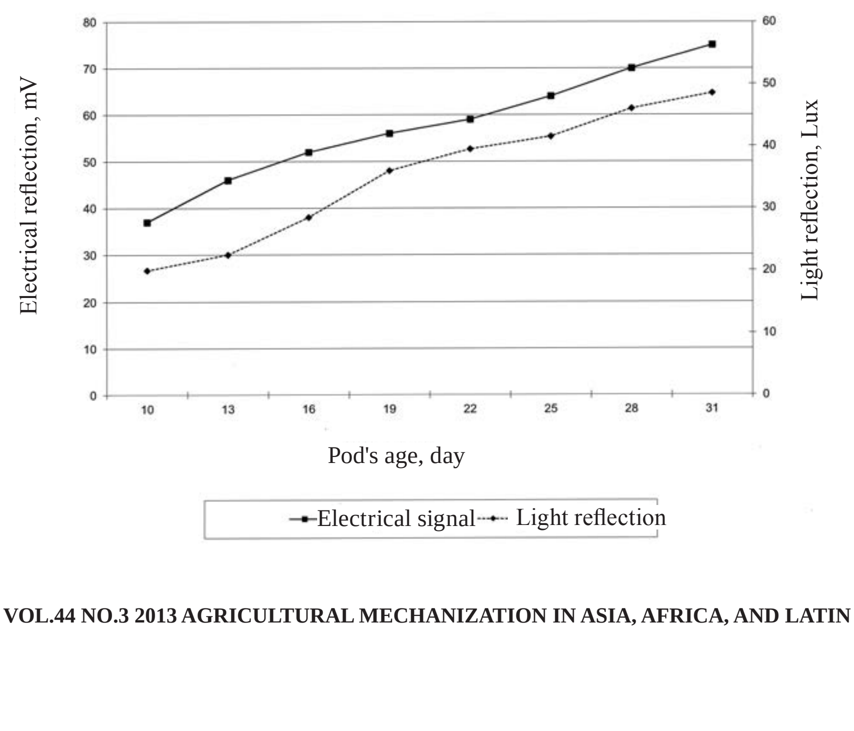


Fig. 8 Comparison between light and electrical signal reflections from green bean pods at different ages using laser 632.8 nm



cal reflection- by using laser at wavelength 632.8 nm- ($E_{632.8}$) and electrical reflection -by using laser at wavelength 543.5 nm- ($E_{543.5}$) for green beans pods at different ages from the appearance of the pods.

For pods at 10 days (first age):

$E_{632.8} = 0.420\ E_{543.5}$ .... (12)

For pods at 22 days:

$E_{632.8} = 0.219\ E_{543.5}$ .... (13)

For pods at 31 days (last age):

$E_{632.8} = 0.114\ E_{543.5}$ .... (14)

Generally, the following equations summarize the relationships between E632.8 and E543.5 as functions of the pod's age (A).

$E_{632.8} = 22.648 + 1.713\ A,$
$R^2 = 0.761,$
$F_{Regression} = 2543$ .... (15)

$E_{543.5} = 18.276 - 0.282\ A,$
$R^2 = 0.310,$
$F_{Regression} = 358$ .... (16)

The **Eqns. 15** and **16** indicate that: the age affects the electrical reflection by using laser at wavelength 632.8 nm more than the electrical reflection by using laser at wavelength 543.5 nm.

Fig. 7 shows the comparison between electrical signal reflections for two wavelengths of green bean pods at different ages from the appearance of the flowers; it is noticed a converse relationship between the two curves. The two curves. The values of 632.8 nm curve are higher than the values of 543.5 nm curve. They illustrate that: when the pod's age from the appearance of the pods from the flowers increase, the electrical signal reflection for He-Ne laser at wavelength 632.8 nm increase gradually from 37 to 75 mV. However, the electrical signal reflection for wavelength 543.5 nm decreased from 15.55 to 8.55 mV.

Figs. 8 and **9** show the relation between light and electrical signal reflections from green bean's pods at different ages using He- Ne laser with two wavelengths. It is noticed that the quantity of electrical signals from laser reflection (632.8 nm) was higher than laser reflection (543.5 nm). Moreover, the figures indicate

Table 6 The electrical reflection (mV) from sweet peas pods at different ages using He-Ne laser with two wavelengths

Pod's age, day	He-Ne laser					
	wavelength 632.8 nm			wavelength 543.5 nm		
	Range, mV	Mean value, mV	Mean electrical reflections, mV	Range, mV	Mean value, mV	Mean electrical reflections, mV
6	29-46	37.5	37.5 ± 8.5	10.2-15.5	12.85	12.85 ± 2.65
9	36-55	45.5	45.5 ± 9.5	8.1-11.5	9.8	9.8 ± 1.7
12	42-66	54	54 ± 12	6.7-9.9	8.3	8.3 ± 1.6
15	47-70	58.5	58.5 ± 11.5	4.8-9.2	7	7 ± 2.2
18	52-74	63	63 ± 11	4.1-8.4	6.25	6.25 ± 2.15
21	56-77	66.5	66.5 ± 10.5	3.6-7.8	5.7	5.7 ± 2.1
24	60-81	70.5	70.5 ± 10.5	3.3-7.2	5.25	5.25 ± 1.95
27	62-84	73	73 ± 11	3-6.6	4.8	4.8 ± 1.8
30	64-85	74.5	74.5 ± 10.5	2.8-6.4	4.6	4.6 ± 1.8
33	65-87	76	76 ± 11	2.6-6.1	4.35	4.35 ± 1.75

Fig. 9 Comparison between light and electrical signal reflections from green bean pods at different ages using laser 543.5 nm

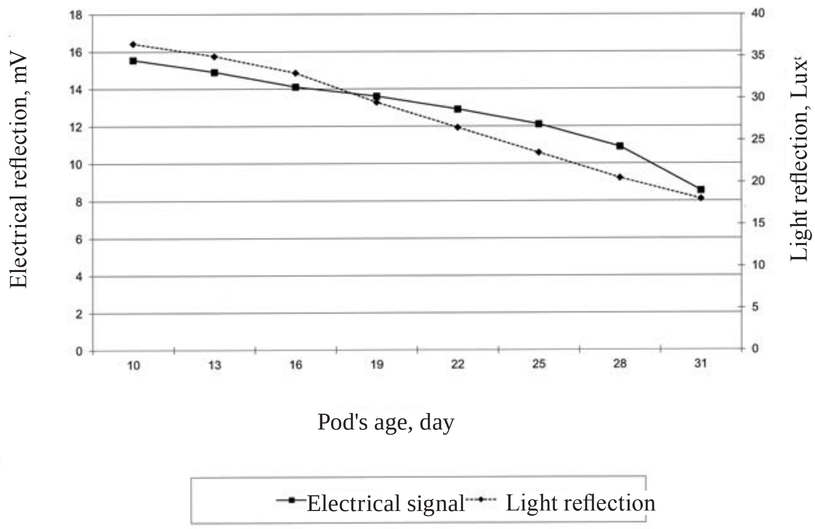
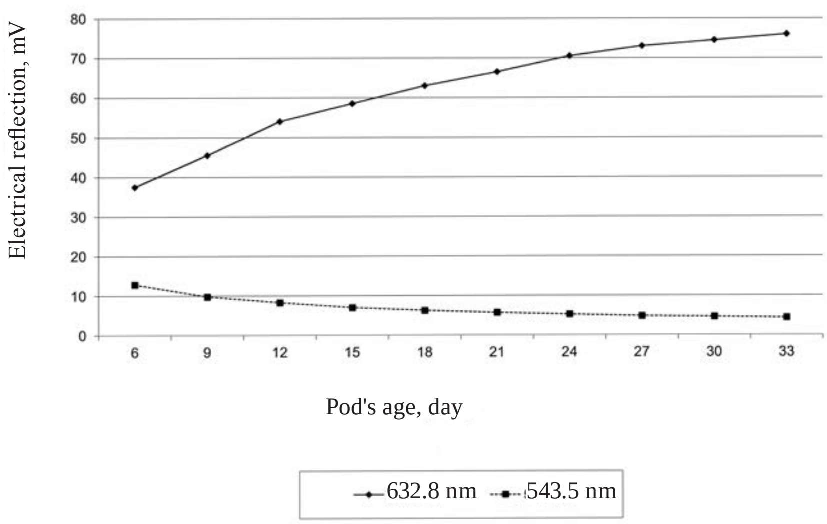


Fig. 10 Comparison between electrical signal reflections for two wavelengths from sweet peas pods at different ages



that by increasing the quantity of optical reflection, the electrical signals increased using laser with wavelength 632.8 nm. Meanwhile, by decreasing the light reflection, the electrical signal decreased using laser with wavelength 632.8 nm.

Sweet Peas Pods:

The values of measured electrical signals from the reflection of laser beam for pods of sweet peas were tabulated in **Table 6**. The table illustrates the electrical signals from the reflection of laser beam which varied at different ages. The values of electrical signals from the reflection laser beam at wavelength 632.8 nm were ranged from (29-46), (36-55), (42-66), (47-70), (52-74), (56-77), (60-81), (62-84), (64-85) and (65-87) mV at pod's ages 6, 9, 12, 15, 18, 21, 24, 27, 30 and 33 days, respectively. And the values were ranged from (10.2-15.5), (8.1 -11.5), (6.7-9.9), (4.8-9.2), (4.1-8.4), (3.6-7.8), (3.3-7.2), (3-6.6), (2.8-6.4) and (2.6-6.1) mV at pod's ages 6, 9, 12, 15, 18, 21, 24, 27, 30 and 33 days, respectively by using laser at wavelength 543.5 nm.

Using the mean values shown in **Table 6**, the following general equations were deduced to express the relationships between electrical reflection by using laser at wavelength 632.8 nm ($E_{632.8}$) and electrical reflection by using laser at wavelength 543.5 nm ($E_{543.5}$) for sweet peas pods at different ages from the appearance of the pods.

For pods at 6 days (first age):

$$E_{632.8} = 0.343\ E_{543.5} \qquad (17)$$

For pods at 18 days:

$$E_{632.8} = 0.099\ E_{543.5} \qquad (18)$$

For pods at 33 days(last age):

$$E_{632.8} = 0.057\ E_{543.5} \qquad (19)$$

Generally, the following equations summarize the relationships between $E_{632.8}$ and $E_{543.5}$ as functions of the pod's age (A).

$$E_{632.8} = 35.531 + 1.360\ A,\quad R^2 = 0.796,\quad F_{Regression} = 3892 \qquad (20)$$

$$E_{543.5} = 12.295 - 0.278\ A,\quad R^2 = 0.728,\quad F_{Regression} = 2670 \qquad (21)$$

Fig. 10 shows the comparison between electrical signal reflections for two wavelengths from sweet peas pods at different ages from the appearance of the pods from the flowers; it was noticed a converse relationship between the two curves. The values of the electrical reflection by using the laser at wavelength 632.8 nm were higher than the values of the electrical reflection at the other wavelength (543.5 nm). It was illustrated that, when the pods age increased, the electrical signal reflection for He-Ne laser at wavelength 632.8 nm increased gradually from 37.5 to 76 mV. However the electrical signal reflection for wavelength 543.5 nm decreased from 12.85 to 4.35 mV.

Figs. 11 and **12** show the relation between light and electrical signal reflections from sweet pea pods at different ages from the appearance of the pods from the flowers using He- Ne laser at two wavelengths. It was noticed that the quantity of electrical signals from the reflection of laser (632.8 nm) was higher than that of the reflection of laser (543.5 nm). In addition, the figures indicate that by increasing the quantity of optical reflection, the electrical signals increased, using laser with wavelength 632.8 nm. Meanwhile, by decreasing the light reflection, the electrical signal decreased using laser with wavelength 632.8 nm.

Fig. 11 Comparison between light and electrical signal reflections from sweet peas pods at different ages using laser 632.8 nm

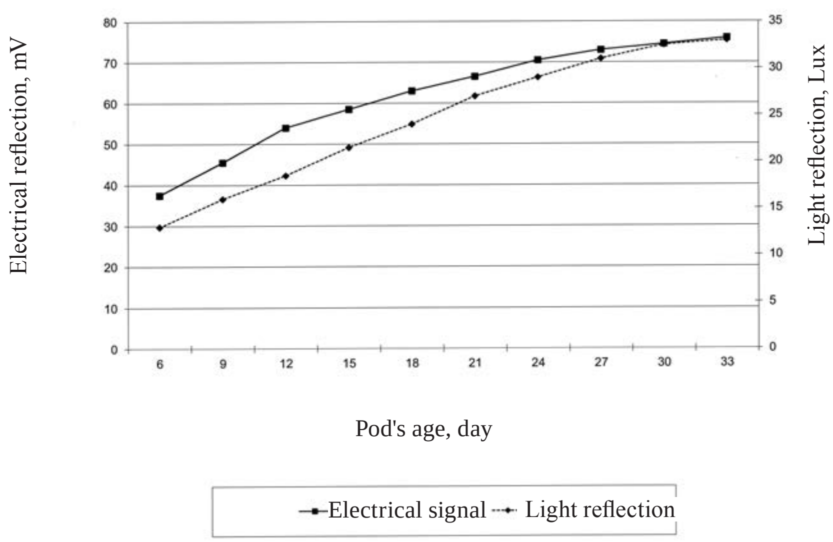
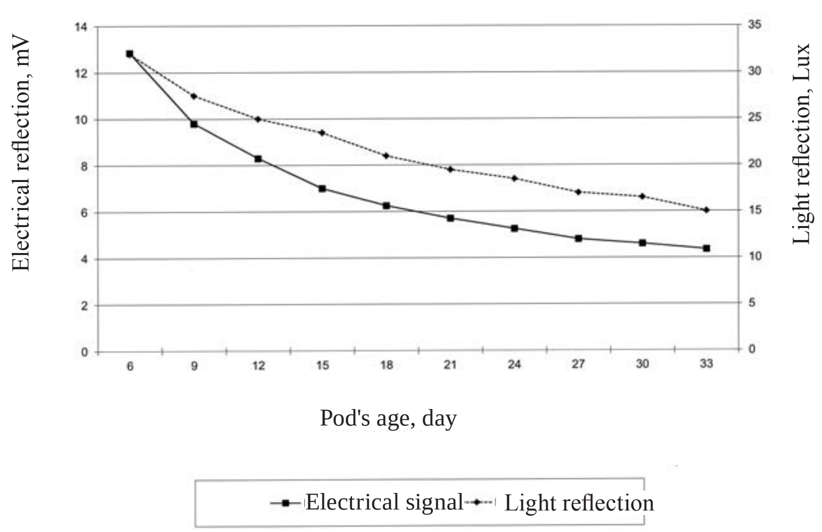


Fig. 12 Comparison between light and electrical signal reflections from sweet peas pods at different ages using laser 543.5 nm



This means that, for first age from the appearance of the pods from the flowers the values of laser light reflection were higher than that of the last ages at wavelength 543.5 nm. However they were smaller than the values at the last age at wavelength 632.8 nm for both green bean and sweet pea pods. Thus, the component of green color was the highest at first age, this component green decreased gradually towards the last age. Therefore, the wavelength 543.5 nm was green color and it gave high reflection with the same color (pods).

From these the He-Ne laser with wavelength 632.8 nm is the suitable laser results high reflection from green bean and sweet pea pods at ages 22 and 18 days, respectively (optimal harvest time) from the appearance of the flowers pods.

Concolusions

From the results obtained, the following conclusions can be made:

1. The values of light reflection intensity were increased by using He-Ne laser (wavelength 632.8 nm) from 15 to 59 Lux for ages of green bean pods from 10 to 31 days, respectively, meanwhile these values were decreased by using He-Ne laser (wavelength 543.5 nm) from 46 to 10 Lux.
2. The values of light reflection intensity were decreased by using He-Ne laser (wavelength 632.8 nm) from 10 to 39 Lux for ages of green peas pods from 6 to 33 days, respectively, meanwhile these values were decreased by

using He-Ne laser (wavelength 543.5 nm) from 35 to 9 Lux.

3. The values of electrical signals were increased by using He-Ne laser (wavelength 632.8 nm) from 30 to 95 mV and ranged from 29 to 87 mV for green peas pod's ages from 6 to 33 days, respectively. But by using He-Ne laser (wavelength 543.5 nm), the values were decreased from 20.5 to 3.8 mV for green peas ages from 10 to 31 days, respectively, meanwhile these values were decreased from 15.5 to 2.6 mV for green pea pods ages from 6 to 33 days.
4. There were relationships between intensity of light and electrical reflections by using two He-Ne laser as a function of the green beans and pea pod's age. And the He-Ne laser with wavelength 632.8 nm is the suitable laser results high reflection from green bean and sweet pea pods at ages 22 and 18 days, respectively (optimal harvest time) from the appearance of the flowers pods.
5. Recommendation of further work would be to design a small apparatus to determine the optimal harvest time of crops on field through exportation time by using visible laser.

REFERENCES

Ahn, S. S. and W. S. Moore. 1992. Endovascular Surgery, Harcourt Brace Jovanovich Inc., London.

Corgan, J. N. 2004. When to Harvest Vegetables. Cooperative Extension Service College of Agriculture and Home Economics.

El-Raie, A. E., H. E. Hassan, and A. A. Abd El-Rahman. 2005. Light and electrical reflections of visible laser for strawberry maturity stages. "Role and horizons of agricultural engineering in the contemporary world". The 13 th Annual Conference of the Misr Soci. of Agric. Eng., 14-15 Dec. 2005: 538-552.

Gitelson A., G. P. Keydan, and M. N. Merzlyak. 2006. Three-band model for noninvasive estimation of chlorophyll, carotenoids, and anthocyanin contents in higher plant leaves. Geophysical Research Letters, Vol. 33, L11402, doi: 10.1029 /2006 GL 026457.

Gitelson, A. and M. N. Merzlyak. 2004. Non-destructive assessment of chlorophyll, carotenoid and anthocyanin content in higher plant leaves: principle and algorithms. Remote Sensing for Agriculture and the Environment. Greece, Ella: 78-94.

Hassan, H. E. 2002. Study of sorting and grading operations of Egyptian mature oranges using visible laser. Ph. D. thesis, National Institute of Laser Enhanced Science (NILES), Cairo Univ., ARE.

Salunkhe, D. K. and S. S. Kadam. 1998. Handbook of vegetable. Production, composition, storage, and processing. Marcel Dekker, Inc. USA. Pp. 437-462.

Slaughter, D. C. 1995. Nondestructive determination of internal quality in peach and nectarine. Trans.of the ASAE. Vol. 38(2): 617-623.

Zur, Y., A. A. Gitelson, O. B. Chivkunova, and M. N. Merzlyak. 2000. The spectral contribution of carotenoids to light absorption and reflectance in green leaves. The second international conference on Geospatial information in agriculture and forestry, Lake Buena Vista, Florida, 10-12 January 2000.

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Field Evaluation of Three Models of TAK* Tractor for Nigeria's Agricultural Transformation

by

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Abstract

In order to boost and encourage commercial farming operation in Nigeria, three models of TAK tractors, namely, TAK DI 750, TAK DI 75 and TAK DI 90 in the range of 37.3 kW (50 hp), 55.95 kW (75 hp) and 67.14 kW (90 hp), respectively, were evaluated at the National Centre for Agricultural Mechanization (NCAM), Ilorin, Kwara State. The objectives were to determine their suitability for use in Nigerian agriculture and for transforming the country's agricultural sector by changing the present farming system from subsistence farming to commercial farming. Evaluation of the three models was carried out at the experimental farm of the National Centre for Agricultural Mechanization (NCAM) using randomized block completed design (RBCD) statistical plot layout to determine operational effects on fuel consumption, travel reduction, tractive efficiencies, as well as field capacity coverage. Results show that fuel consumption was higher for ploughing operations varying between 5.90 L/ha and 6.80 L/ha than harrowing operations varying between 0.85 L/ha and 1.20 L/ha for the three tractor models. So also were the results of field efficiencies which varied between 73.56 % and 84.74 % and 75.36 % and 84.55 % for ploughing and harrowing operations, respectively. Also, the travel reduction and field operational efficiencies were higher for TAK models DI 750 than the other two models, the results for fuel use and draught force did not follow such trend, being governed more by soil conditions at the time of investigation. The results further shows that tractor size has overriding influence on fuel consumption and tractive performance while soil condition greatly influenced the performance of the three tractor models. Among the three sets of TAK tractor models tested using the same tractor operator to operate these tractors, TAK DI 750 tractor during ploughing operation performed better in terms of economic value by having the lowest fuel consumption rate of 5.90 L/ha, lowest drawbar power of 8.08 kW and highest field efficiency of 84.74 %. This was immediately followed by TAK DI 75 tractor which recorded a fuel consumption rate of 6.30 L/ha, a drawbar power of 9.49 kW and a field efficiency of 78.77 %. Finally, TAK DI 90 tractor recorded a fuel consumption rate of 6.80 L/ha, a drawbar power of 9.72 kW and a field efficiency of 73.56 %.

Introduction

Most farming operations in Nigeria are accomplished through the use of hand hoes and cutlasses which are labour intensive, time consuming, drudgery laden and expensive. This traditional method of farming in Nigeria puts serious limitations on the growth of the nation's agricultural sector thus exacerbating reduced food production leading to increased food importation. This situation is contrary to envisaged increased agricultural productivity in a country blessed with abundance of natural resources.

Africa has sustained a relatively high growth rate since the turn of the century, averaging more than 5 percent per year. This performance improvement, widely shared across countries, has raised hopes of a possible turnaround, compared to the stagnation of the previous two decades (1991-2010). Yet this growth did not result in significant generation of employment or wealth or improved welfare for ordinary citizens. One of the key explanations for this

*TAK is the Trade Name for the tractor models locally assembled and marketed by TAK Tractors Limited, Kaduna, Nigeria non-inclusive growth pattern is Africa's heavy dependence on primary production and exports of agricultural commodities and limited economic transformation.

The stylized facts of economic transformation broadly suggest that as the real per capita income of an economy increases over the long term:

- the share of agriculture in gross domestic product (GDP) and total employment will decline;
- the share of the industrial sector in GDP will rise, the share of manufacturing subsector in GDP will rise;
- the share of the services sector will increase;
- the employment share of the agricultural sector in total employment will decline; and
- the ratio of average labour productivity outside agriculture to that in agriculture will increase.

African economies are still dominated by agriculture and extractive sectors. Heavy dependence on primary commodity sectors increases exposure to economic volatility and enhances vulnerability to external shocks. It has also contributed to Africa's sustained high unemployment and the prevalence of vulnerable, predominantly informal-sector employment. The persistent dependence of Africa on primary commodity is not the result of a lack of efforts by governments to remedy the situation. However, Africa's previous experiences with a range of alternative development approaches have so far failed to successfully address these structural distortions.

Agriculture plays a major role in developed nation's economy. Therefore the word, agriculture, as defined by Lasisi (2010) is the production of food and goods through farming. Agriculture was the key development that led to the rise of human civilization, with the husbandry of domesticated animals and plants (i.e. crops), creating food surpluses that enabled the development of more densely populated and stratified societies. Cultivation of crops on arable land and the pastoral herding of livestock on rangeland remain at the foundation of agriculture.

Engineering has impacted positively on agriculture in modern times. Makanjuola (1977) defined Agricultural Engineering as that field of engineering in which the physical and biological sciences are utilized to find and apply better ways of exploiting natural resources for the production, handling, processing and storing of food and fodder. It is also concerned with finding better ways of carrying out such allied activities as rural housing and living. Agricultural Engineering consequently involves the design, development, testing, manufacturing, marketing, operation, maintenance, and repair of all agricultural tools, implements, machines and equipment which are used in mechanizing agricultural operations with the objective of increasing the productivity of human labour and land in the face of prevailing economical, human and social realities of the time and place concerned.

Agricultural mechanization can be defined as any means that can be employed in the process of agricultural production (Lufti and Al-Khafat, 1988). It includes the use of hand, animal and engine-powered implements and machines in production, processing, transportation and marketing of agricultural products.

Agricultural tillage involves soil cutting, soil turning, and soil pulverization and thus demands high energy, not just due to the large amount of soil mass that must be moved, but also due to inefficient methods of energy transfer to the soil. The most widely used energy-transfer method is to pull the tillage tool through the soil. Various methods have been attempted to improve efficiency such as vibratory tillage tools. However, development of more efficient methods effectively depends upon the necessity for improved understanding of tillage tool mechanics. Complete tillage mechanics is far from being realized, although generalized relations have been proposed (Fornstrom *et al.*, 1970).

In Nigeria, the common commonly employed tractors are within 40 to 60 kW (Osoba, 1976). The primary purpose of agricultural tractors, especially those in the middle to high power range, is to provide power to enable attached soil engaging and other agricultural implements to perform their intended functions. The value of a tractor is measured by its power rating and the amount of work accomplished relative to the cost incurred in getting the work done. Drawbar power is that achieved through the drive wheel to move the tractor and or implements through the soil.

Drawbar power can be expressed as the product of pull and travel speed. Therefore, the ideal tractor converts all the energy from the fuel into useful work at the drawbar. In practice, most of the potential energy is lost in the conversion of chemical energy to mechanical energy, along with losses from the engine through the drive train and finally through the tractive device. Research shows that about 20 % to 55 % of the available tractor energy is wasted at the tractive device/soil interface. This energy wears the tyres and compact the soil to a degree that may cause detrimental crop production (Zoz and Grisso, 2003).

The performance of tractor depends on the performance of a combination of traction devices and the performance of the tractor drive train. While the efficiency of a traction device is defined as tractive efficiency, the efficiency of a complete tractor is defined as power delivery (Zoz *et al.*, 2002).

The attributes of an efficient operation of farm tractors include maximizing the fuel efficiency of the engine and drive train, maximizing the tractive advantage of the traction devices and selecting an optimum travel speed for a given tractor implement system (Zoz and Grisso, 2003).

Draft and energy requirements, based on current soil and operating conditions, are considered important parameters for design and manufacture of improved tillage implements. Thus quantification of these parameters with respect to different soil failure patterns necessitates having good knowledge of soil-tool interaction. Tillage tools apply forces to soil resulting soil failure for enhanced seedling emergence, improved plant rooting, increased infiltration rate, and controlled soil erosion (Ellison, 1947; Lindstrom *et al*., 1990). The primary interest in tillage operations is the application of mechanical forces by machines to change the soil condition for agricultural production purposes (Schafer and Johnson, 1982). The continuous use of agricultural tractors with its tillage implements remains the only way to tackle food demand of the ever-increasing world population by rapidly bringing more farm land under cultivation.

Traction is that force derived from the interaction between a device and a medium in order to facilitate a desired motion over the medium (Bill and Vanden Berg, 1968). This force is important for powered pneumatic tyre type tractive devices and has been an area of study for many years. Raghavan and Mckynes (1979) found that wheel slippage is a function of tyre inflation pressure, tyre size, tyre shape, tyre flexibility and soil type. Travel reduction, according to Berger *et al.* (1963), is the slippage of a traction member when a wheel or track propels a tractor with or without an attached load over the medium.

Nigeria has over the years, been recognized as a country for dumping of agricultural machines, tools and equipment that are no longer of value and not readily applicable to farming condition of their countries of origin. This dumping syndrome has led to the high number of tractor breakdowns in the country. The syndrome has also made many farmers to have no regard for the use of tractor power and thus their resolve to continue with the use of hand hoe and cutlass for the cultivation of land. Most places where tractor custom hiring operations are being rendered in the country, most of the available tractors are either not in good working condition or totally grounded. All these are the discouraging experiences of farmers who had ones put their hope in the use of tractor power. At the end, the tractor power which would have been the only way to encourage farmers to cultivate large areas of land for commercial farming became a story of the past due to constant recurrence of tractor breakdowns. These farmers are left with no other option, than to resort to the traditional way of farming which could only produce food for their immediate household.

In the United States of America today, the Nebraska Tractor Test Laboratory (NTTL) at the University of Nebraska is the officially recognized tractor-testing station for the Organization for Economic Cooperation and Development (OECD). This laboratory is responsible for testing a representative tractor of each model sold in USA. It also tests tractors manufactured in the United States and sold in international markets.

In order to overcome this ugly scenario of constant breakdown of tractors recorded in almost every part of the country, the National Centre for Agricultural Mechanization (NCAM), Ilorin, was established to test all kinds of agricultural machinery, tools and equipment imported into the country. Test reports issued by NCAM are meant to guide end-users and farmers in selecting suitable tractor-implement combination for cost-effective operations.

The main objective of this study was to conduct test on three locally assembled TAK tractor models in order to ascertain their suitability and adaptability to the Nigerian agro-climatic conditions.

Other specific objectives of this study included:-

1. Determining the tractor's fuel use for cost-effective operation.
2. Determining the tractive efficiency of each of the tractor tested.
3. Determining the drawbar power of each of the tractor tested.
4. Guiding end-users on any given tractor to be employed based on efficient field operation and minimum optimum fuel consumption rate.

Materials and Methods

Field evaluation of the three tractor models under consideration were carried out at the experimental farm of the National Centre for Agricultural Mechanization (NCAM), Ilorin, in the month of April, 2009 under varying soil conditions. Experimental design for the field evaluation was randomized complete block design (RCBD) replicated three times. The soil textural classification for the site was sandy loam. Each plot size was half a hectare (50 m by 100 m). Parameters measured include travel speed for each tractor models that was measured by determining the average time it took the tractor to cover the longest distance; fuel consumed for each tillage operation was measured by starting each tillage operation by filling the fuel tank and then refilling after completing the operation; time factors such as actual time, total time, obstruction time and turning time used for completing each tillage operation were measured with a stop watch; sound level readings of each tractor during each tillage operation was recorded using the sound level analyzer; draught force was recorded through the use of a dynamometer; width and depth of cut were measured through the use of a measuring tape; soil cone index was recorded using the digital cone penetrometer; soil shear strength was measured using the soil shear vane, soil moisture content was determined through the use of the oven dried method; and soil bulk density was determined from the mass per unit volume of soil. All the parameters of the tractor-implement performance were measured and recorded in line with the recommendations of Regional Network for Agricultural Machinery (RNAM) test codes and procedures for farm machinery technical series (1995).

Test Parameters

The following test parameters were adopted for this tractor evaluation.

Effective field capacity

Effective field capacity measured in (ha/hr) can be expressed mathematically as:

$D = 3600E / F$ ....(1)

where,

D = effective field capacity (ha/h)

E = area of field (ha)

F = total time taken in completing the whole tillage operation (sec)

Theoretical field capacity

Theoretical field capacity measured in (ha/h) can be expressed mathematically as:

$G = 3600E / F_1$ ....(2)

where,

G = theoretical field capacity (ha/h)

E = area of field (ha)

F_1 = actual time taken in doing the main tillage work (sec)

Field efficiency

Field efficiency measured in (%) can be expressed mathematically as:

$H = D / G \times 100\ \%$ ....(3)

where,

H = field efficiency (%)

D = effective field capacity (ha/h)

G = theoretical field capacity (ha/h)

Fuel consumption

Fuel consumption measured in either (L/ha) or (L/h) can be expressed mathematically as:

$I = J / E$ ....(4)

and

$K = DJ$ ....(5)

where,

I = fuel consumption (L/ha)

J = volume of fuel consumed (L)

E = area of plot (ha)

K = fuel consumption (L/h)

D = effective field capacity (ha/h)

Travel reduction (wheel slippage)

Travel reduction (wheel slippage) measured in (%) can be expressed mathematically as:

$L = (M_2 - M_1) / M_2 \times 100\ \%$ .....(6)

where,

L = travel reduction/wheel slippage (%)

M_2 = distance covered at every 10 revs of the wheel at no-load condition (m)

M_1 = distance covered at every 10 revs of the wheel at load condition (m)

Tractor's drawbar power

Tractor's drawbar power is measured in (kW) can be expressed mathematically as:

$N = (D_f \times S_o) / 3.6$ *(constant)* ...(7)

where,

D_f = Draught (kN)

S_o = Speed of Operation (km/h)

Tractive efficiency

Tractive efficiency is measured in (%) can be expressed mathematically according to (Macmillan, 2002) as:

$\eta_t = Q_d / Q_w \times 100\ \%$ ....(8)

where,

η_t = tractive efficiency (%)

Q_d = drawbar power (kW)

Q_w = wheel power (kW),

we assume power losses in the transmission from engine to the wheels of, say 10 %, then the expression becomes:

$\eta_t = Q_d / (0.9 \times Q_e)$ ....(9)

where,

η_t = tractive efficiency (%)

Q_d = drawbar power (kW)

Q_e = engine power (kW)

Table 1 Tractors specifications

Parameters	TAK TRACTORS		
Tractor Model	TAK DI 750	TAK DI 75	TAK DI 90
Effective Output Hp (kW)	50 (37.3)	75 (55.95)	90 (67.14)
Type of Engine	3-Cylinder	4-Cylinder	4-Cylinder
Type of Fuel	Diesel		
Tractor Type	Rear Wheel Drive	Rear Wheel Drive	Four Wheel Drive
Type of Steering System	Power -assisted steering		
Type of Injector Pump	In -line Injector System		
Firing Order	1-2-3	1-3-4-2	1-3-4-2
Fuel Tank Capacity (L)	55	65	65
Lifting Capacity (kg)	1,200	2,500	2,800
Crankshaft Rated Speed (rpm)	2,100	2,200	2,200
Type of Cooling System	Water-Cooled		
Country of Origin	India		

Table 2 Implements specifications

Specifications	Disc Plough	Offset Disc Harrow
Implement type	Mounted	Mounted
Overall length (mm)	2,022	1,087
Overall Width (mm)	880	1,084
Overall height (mm)	1,016	1,026
Number of bottoms/blades	3	18
Lower hitch point span (mm)	880	750
Diameter of disc (mm)	660	-
Diameter of plane blade (mm)	-	570
Diameter of notched blade (mm)	-	560

Results and Discussion

The specifications for the three tractor models and implements used for the study are presented in **Tables 1** and **2**, respectively. The results of the data collected for the three tractor models for each tillage operation are as presented in **Tables 3** and **4**, while the effects of tractor performance on soil physical properties during ploughing and harrowing operations are as presented in **Tables 5** and **6**.

Fuel Consumption

Results presented in **Tables 3** and **4** showed that for all implements (plough and harrow), mounted on the three different TAK tractors, the fuel consumption ranged between 5.90 L/ha and 6.80 L/ha for ploughing operation and between 0.85 L/ha and 1.20 L/ha for harrowing operation. In both tillage operations carried out by the three tractor models, TAK DI 750 tractor of 50 hp (37.3 kW), exhibited the least fuel consumption value of 5.90 L/ha and 0.85 L/ha for ploughing and harrowing operations, respectively. Likewise, TAK DI 750 tractor exhibited the least drawbar power of 8.08 kW and 4.74 kW for ploughing and harrowing operations, respectively. These show that the drawbar power and the fuel consumption rate of a tractor are positively correlated thereby signifying that the higher the drawbar power the higher the fuel consumption rate irrespective of the tillage operation carried out as shown in **Tables 3** and **4**.

Table 3 Results of field test on the three tractor models during ploughing operation

DATA	TAK TRACTORS		
Tractor model	TAK DI 750	TAK DI 75	TAK DI 90
Wheel Slippage (%)	5.32	20.00	6.85
Area of land (ha)	0.50	0.50	0.50
Average Width of Cut (cm)	126.00	132.00	124.00
Average Max. Depth of Cut (cm)	25.00	24.50	27.00
Operational Speed (km/h)	5.82	5.58	6.47
Effective Field Capacity (ha/h)	0.7423	0.6315	0.6102
Average Time of Operation (h/ha)	1.347	1.584	1.639
Field Efficiency (%)	84.74	78.77	73.56
Draught Force (kN)	5.00	6.12	5.41
Tractive efficiency (%)	24.08	18.84	16.09
Sound Level under working condition (dB)	68.86	76.88	70.86
Fuel Consumption (L/ha)	5.90	6.30	6.80
Fuel Consumption (L/h)	4.38	3.98	4.15
Tractor's drawbar power (kW)	8.08	9.49	9.72
Tractor's power hp (kW)	50 (37.3)	75 (55.95)	90 (67.14)

Table 4 Results of field test on the three tractor models during harrowing operation

DATA	TAK TRACTORS		
Tractor model	TAK DI 750	TAK DI 75	TAK DI 90
Wheel Slippage (%)	19.27	6.79	6.07
Area of land (ha)	0.50	0.50	0.50
Average Width of Cut (cm)	176.67	180.00	156.67
Average depth of Cut (cm)	22.00	13.00	16.00
Operational Speed (km/h)	6.66	6.98	7.57
Effective Field Capacity (ha/h)	0.9756	1.0315	1.4694
Average Time of Operation (h/ha)	1.025	0.969	0.681
Field Efficiency (%)	84.55	75.36	76.33
Draught Force (kN)	2.56	3.63	3.61
Tractive efficiency (%)	14.11	13.98	12.56
Sound Level under working condition (dB)	75.50	67.11	70.33
Fuel Consumption (L/ha)	0.85	0.90	1.20
Fuel Consumption (L/h)	0.83	0.93	1.76
Tractor's drawbar power (kW)	4.74	7.04	7.59
Tractor's power hp (kW)	50 (37.3)	75 (55.95)	90 (67.14)

Tractive Efficiency

The calculated tractive efficiency values of the three tractors evaluated as shown in **Tables 3** and **4** showed that tractive efficiency varied between 16.09 % and 24.08 % for ploughing operation and between 12.56 % and 14.11 % for harrowing operation. These low values of tractive efficiency recorded in both tillage operations is an indicative of the energy potentials of these tractor models for tillage work. This available energy makes these tractors highly useful in places where we have heavier agricultural implements and sub-optimum soil conditions.

Sound Level

The sound level recorded under tractor working condition for these three tractors during tractor-test whose values varying between 67 dB and 77 dB as shown in **Tables 3** and **4**, showed that they were all within the acceptable human hearing limit and hence considered safe for the tractor operator.

Soil Cone Index

Soil measurements taken for soil cone index during tractor-test as shown in **Tables 5** and **6** showed that the average cone index recorded after ploughing and harrowing operations was lower than the average cone index recorded before ploughing and harrowing operations. This is attributed to the fact that before carrying out any tillage operation,

Table 5 Effect of field operation on soil physical properties during disc ploughing

Tractor Model	Before operation				After operation			
	AMC (%)	ABD (g/cm^3)	ACI (N/cm^2)	ASS (MPa)	AMC (%)	ABD (g/cm^3)	ACI (N/cm^2)	ASS (MPa)
TAK DI 750	8.56	1.45	47.79	0.037	8.60	1.31	24.12	0.012
TAK DI 75	9.07	1.49	65.20	0.048	9.41	1.38	17.22	0.013
TAK DI 90	8.96	1.42	63.16	0.044	12.20	1.24	14.93	0.012

AMC = Average Soil Moisture Content (%); ABD = Average Soil Bulk Density (g/cm^3); ACI = Average Cone Index (N/cm^2); ASS = Average Shear Strength (MPa)

Table 6 Effect of field operation on soil physical properties during disc harrowing

Tractor Model	Before operation				After operation			
	AMC (%)	ABD (g/cm^3)	ACI (N/cm^2)	ASS (MPa)	AMC (%)	ABD (g/cm^3)	ACI (N/cm^2)	ASS (MPa)
TAK DI 750	8.42	1.18	15.28	0.008	8.48	1.15	10.15	0.006
TAK DI 75	8.92	1.31	17.00	0.015	8.95	1.26	8.04	0.006
TAK DI 90	11.10	1.22	10.34	0.009	11.05	1.18	6.90	0.006

AMC = Average Soil Moisture Content (%); ABD = Average Soil Bulk Density (g/cm^3); ACI = Average Cone Index (N/cm^2); ASS = Average Shear Strength (MPa)

the soil in its undisturbed form is in its harden state, but as tillage operation takes place in such an area, the soil becomes soft and the cone penetrometer finds it easy to penetrate deeply into the soil.

Soil Moisture Content

Soil moisture during tractor-test as shown in **Tables 5** and **6** showed that all the average soil moisture taken before ploughing and harrowing operations was lower than the average soil moisture taken after tillage operation. This is so because before tillage operation the deeper soil profile would normally contain more moisture than the top soil layer.

Tractor's Assessment

The best way to assess these tractors based on their performance was based on ploughing operation which is usually associated with high fuel consumption rate, time-consuming operation, high energy consumption rate, etc. Among other tillage operations, the performance of these three tractors was based on fuel consumption rate, drawbar power and field efficiency. As a result, among the three sets of TAK tractor models tested with the same operator, TAK DI 750 tractor performed better in terms of economic value by having the lowest fuel consumption rate of 5.90 L/ha, lowest drawbar power of 8.08 kW and highest field efficiency of 84.74 %. This was immediately followed by TAK DI 75 tractor which recorded a fuel consumption rate of 6.30 L/ha, a drawbar power of 9.49 kW and a field efficiency of 78.77 %. Finally, TAK DI 90 tractor recorded a fuel consumption rate of 6.80 L/ha, a drawbar power of 9.72 kW and a field efficiency of 73.56 %.

Conclusions

Ploughing operation being the most energy demanding for tillage operation resulted in higher fuel consumption rate and higher average time of operation. Hence, ploughing operations would cost more than any other tillage operation. All the three tractor models performed well based on established standards. From the standpoint of field efficiency, drawbar power and fuel economy, the tractor model TAK DI 750 of 50 hp (37.3 kW)

Fig. 1 TAK DI 750

Fig. 2 TAK DI 75

Fig. 3 TAK DI 90

had a field efficiency of 84.74 %, drawbar power of 8.08 kW and fuel consumption rate of 5.90 L/ha during ploughing operation. Therefore, the TAK DI 750 tractor would be preferred among the tractor models.

To guide farmers on the selection of tractors size, tractors of lower (kilowatts) power, between the ranges of 50 hp to 60 hp, would be preferred for tillage operations because of the high fuel economy exhibited by these tractors when compared to tractors of higher (kilowatts) power.

Custom hiring of tractors to perform tillage operations would result in lower cost than employing human labour. Hence, the use of farm tractors in Nigeria should be encouraged for commercial farming operations.

Farmers and dealers should liaise with appropriate government authorities in knowing the tractors certified by the National Centre for Agricultural Mechanization (NCAM), Ilorin, before such tractors are purchased for use in the country. State and local governments are also encouraged to do same so as to move the country's agricultural development to a greater height.

No statistical analysis was carried out on the results obtained to establish their confidence level.

REFERENCES

Berger, E. L., J. B. Liljedahl, and E. C. Mckibben. (1963). Tractors and their Power Units. 2nd Edition. John Wiley & Sons Inc., New York.

Bill, R. W. and G. E. Vanden Berg. 1968. Soil Dynamics in Tillage and Traction. The Superintendent of Documents, U.S. Govt. Publishing Office, Washington, D.C. 20401, U.S.A.

Ellison, W. D. 1947. Soil erosion studies-part II. Agricultural Engineering 28: 197-201.

Fornstrom, K. J., R. D. Brazee, and W. H. Johnson. 1970. Tillage-tool interaction with a bounded, artificial soil. Transactions of the ASAE, 409 - 416.

Lasisi, F. 2010. Agricultural Engineering and Society- The Challenges and Sustainability. Being a paper presented at the 1st Departmental Lecture organized by the Department of Agricultural and Biosystems Engineering, University of Ilorin, Ilorin, Nigeria on 1st June, 2010.

Lindstrom, M. J., W. W. Nelson, T. E. Schumacher, and G. D. Lemme. 1990. Soil movement by tillage as affected by slope. Soil & Tillage Research 17: 225-264.

Lufti, H. M. A. and A. M. Al-Khafat. 1988. Status of farm Mechanization in Iraq. A.M.A. 19 (2): 69-73.

Macmillan, R. H. 2002. The Mechanics of Tractor-Implement Performance: Theory and Worked Examples. A Textbook for Students and Engineers.

Makanjuola, G. A. 1977. Agricultural Mechanization in Nigeria: The prospects and Promises., Inaugural Lecture, Series No. 25, University of Ife.

Osoba, A. 1976. Position of Mechanization in Western Nigeria. Paper presented at Inter-African Committee of Agricultural Mechanization. Organization of African Unity, Rome.

Raghavan, G. S. U. and E. Mckynes. 1979. Performance of Traction wheel in Clay Soil. Transaction of ASAE 22(2): 229-232.

RNAM. 1995. Regional Network for Agricultural Machinery Test codes and Procedures for Farm Machinery. Technical Series No. 12. General Guidelines in the use of Test Codes.

Schafer, R. L. and C. E. Johnson. 1982. Changing soil condition-The soil dynamics of tillage. In: Tillage Effects on Soil Physical Properties and Processes. American Society of Agronomy Special Publication, Number 44, 14-15. Madison.

Zoz, F. M., R. L. Turner, and L. R. Shell. 2002. Power Delivery Efficiency: A Valid Measure of Belt and Tire Tractor Performance. Trans. ASAE, 45 (3): 509-518.

Zoz, F. M. and R. D. Grisso. 2003. Traction and Tractor Performance, ASAE Distinguished Lecture Series #27, ASAE Publication Number 913C0403. Paper presented at the Agricultural Equipment Technology Conference held at Louisville, Kentucky, USA, February 9 -11.

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Improved Project Implementation through Virtual Prototyping. A Case Study of Farm Produce Handling Technologies for Small Scale Farmers in South Africa


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Abstract

In order to enhance development of agricultural post harvesting and farm produce handling technologies, virtual engineering tools were utilized for functional visualization, evaluation and decision making of intended infrastructure outcomes without physical modelling. This technological advancement facilitates down streaming issues during the preliminary stages of projects development. This paper showcase how virtual prototyping is being utilized in the post harvesting and farm produce handling technology development for small scale farmers in South Africa. These tool assisted researcher engineers visualise and appreciate intended design outcomes without physical modelling. It was also realised that virtual reality (VR) introduction facilitated designs interpretations during the preliminary stages through elaborative visualisation. The project was a collaborative effort of various institutes to enhance research engineers' interest in visual design and graphics while stimulating interest in leading-edge technology. Although the topic requires further investigations, and if research is to be believed, it can be concluded that the introduction of virtual prototyping improves post harvesting technology appreciation by learners, end-users and the small scale farming communities in South Africa.

Introduction

In small scale post harvesting handling systems research especially for design and development, the most effective way to improve junior research engineers' ability to visualize 3-D designs is to make their learning experience as realistic as possible. However, in general, it is very difficult to clearly describe to researchers a 3-D agro processing system components and the spatial relationship between the prototype components, without using a physical mock up. Physical mock-ups take a long time to construct, especially for more complex objects like the integrated post harvesting handling system prototype. As a result, research engineers at the Agricultural Research Council's Institute for Agricultural Engineering have started utilising Virtual Reality (VR) tools to help their colleagues understand the spatial relationships between objects. However, CAD (Computer-Aided Design) tools only allow trainees to examine models from outside flat computer monitors. In other words, the models and the viewers are in different realms. Using traditional CAD tools, researcher engineers cannot view models with natural stereoscopic vision.

Virtual reality is a computer technology of simulating or replicating a physical environment to give users a sense of being there, taking control, and physically interacting with the environment (Ausburn & Ausburn, 2004). VR technology breaks down barriers between humans and computers by immersing viewers in a computer-generated stereoscopic environment. With advances in hardware and software, most PC computers now have the capability to support VR use. As Ausburn and Ausburn (2004) indicated that there was a significant opportunity to expand and explore the use of VR in the design review. Research suggests that VR is an effective tool that enhances knowledge interchange in areas such as engineering (Sulbaran & Baker, 2000). In addition, VR engages the intellectual, social, and emotional processes of learners. The impact of VR is due to its ability to encourage interaction and ability to motivate learners (Winn *et al*., 1997). Salzman (1999) found that VR applications in informative sessions depends on VR features, contents, junior researcher engineers' characteristics, and trainees' prior experiences. With regards to agro processing infrastructures development, the emphasis of engineering graphics education has been placed on design, problem-solving, presentation, and communication skills. The 3-D spatial visualization ability is the core requirement for successfully developing those skills. The use of VR may also represent an effective strategy that supports the development of spatial skills. It is important to combine exposure to VR models with activities such as sketching or drawing as a means for developing a capacity for visual imagery and creativity (Deno, 1995; Devon *et al*., 1994; Sorby, 1999). Sorby (1999) explained that in most cases, prototype development begin with multi-view sketching/drawing and then move to pictorial sketching. However, this sequence of topics is opposite of how most tutors say that research engineers learn., It is important to consider challenges in integrating VR in the prototype development process. There is little guidance regarding the instructional design and information room facilitation of VR technologies (Ausburn & Ausburn, 2004). These challenges include lack of necessary computing equipment for testing VR applications (Riva, 2003), lack of standardization of VR systems (Riva, 2003), and difficulty in establishing equivalent control groups (Crosier *et al*., 2000).

This paper examines the use of VR at the ARC-IAE including the agro processing and post harvesting division. This paper considers how the use of new technology in agro processing infrastructures development affects the researcher engineers. Experiences and survey results are presented for interested researchers to follow.

Materials and Method

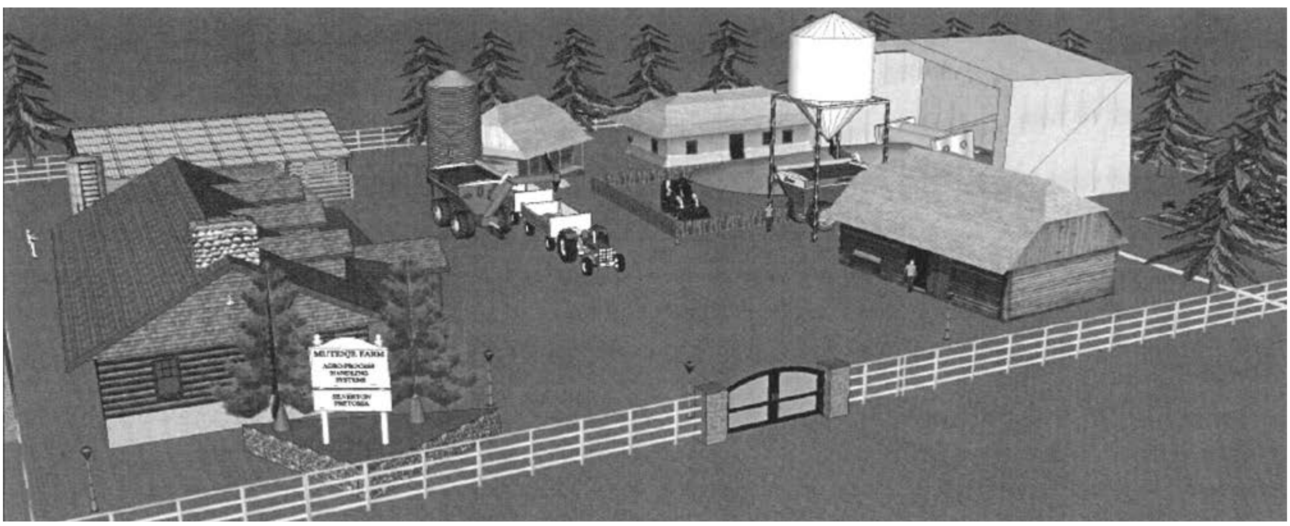
A VR software tool, REVIT, and instructional materials necessary for design visualisation use such as a variety of system prototype were developed. The institute utilises open source VR software.

Project Activities

During the project year, this tool was used for agricultural post harvesting and processing infrastructures design and prototype design courses for both Students and qualified research engineers. **Fig. 1** shows a virtual prototype of an integrated agro processing and post harvesting handling system from one of the design classes. Research engineers were taught about orthographic projection as a part of their drafting studies. Traditionally, this unit of instruction requires the research engineers to identify surfaces and classify them (normal, inclined, and oblique). They were also asked to examine a drawing of an object with a set of orthographic views and to identify and classify surfaces according to information from the drawing. With the advent of computer technology, VR becomes another avenue by which the instructors can attempt to reach these research engineers.

During the information interchange, produce handling and agro-processing systems models were projected onto the screen. Once research engineers had shown an understanding of the differences between the surfaces, and their roles within the orthographic system, more complex models were pre-

Fig. 1 Virtual prototype of an integrated agro-processing and produce handling system (after Mutenje, 2011)



sented for them to practice. Through these exercises, the engineers were allowed to develop an understanding of the process of these handling systems, relating surfaces and edges to their representation in orthographic views as illustrated in **Fig. 2** below.

After attending the illustrative course, most participants demonstrated increased interest of enhancing their careers in agricultural infrastructures, agro-processing and produce handling systems and technology. Approximately 74 % of the participants in the course indicated that availability of VR would be a factor in their choice of technology in agro-processing farming technology development. More male than female engineers indicated that the availability of VR would be a more important factor in their technology choice. Engineers also expressed that learning with VR gave them a better understanding of infrastructure development than by traditional methods. Before these researchers attended the course, there was also a significant difference between male and female researchers in their responses concerning their interest in enhancing careers in agro-processing farming systems design and development. However, the differences in male and female researcher engineers' attitudes faded away after they were exposed to VR in the training sessions.

Evaluation Process

In this project, various tests and surveys were administrated to examine junior researchers' conceptual growth and changes in their spatial abilities and session's engagement. Reports from the focus groups conducted in the project duration, and comments from the open-end questions from the engineers' survey supported the quantitative evaluation activities. The results from the evaluation provided clear evidence on how the use of VR influenced junior researcher engineers' understanding of spatial concepts of agro-processing systems development. Spatial ability has been shown to be positively correlated with retention and achievement in engineering disciplines (His *et al.*, 1997). Spatial ability has identified several different spatial domains, including spatial visualization and spatial orientation. Spatial visualization refers to the ability to image the movements of objects and spatial forms, and involves tests of mental rotation. Spatial orientation refers to the ability to imagine the appearance of objects from different orientations of the observers. The improvements of junior research engineers' spatial abilities were measured with specific measures, such as the Mental Rotation Test (MRT) and the Picture Test (PT) developed by Hegarty and Waller (2004). Mental rotation is somewhat localized to the right cerebral hemisphere. It is thought to take place largely in the same areas as perception. It is associated with the rate of spatial processing and intelligence (Johnson 1990, Jones 1982, Hertzog 1991)

Results and Analysis

Influence on Spatial Ability

Survey results showed that VR was an efficient instructional method to develop the spatial ability of junior research engineers who were encountering problems to understand the agro-processing and produce handling system development process. Engineers who performed poorly in the pre-PT were more likely to improve their post-test scores than those who did better in the pre-test. In surveys, researchers also noted that, with the new VR tools and learning methods, they were able to better see and understand examples that related to even more complicated facilities. Researcher engineers further explained that they were able to see inside

Fig. 2 Inside view of handling systems (after Mutenje, 2011)

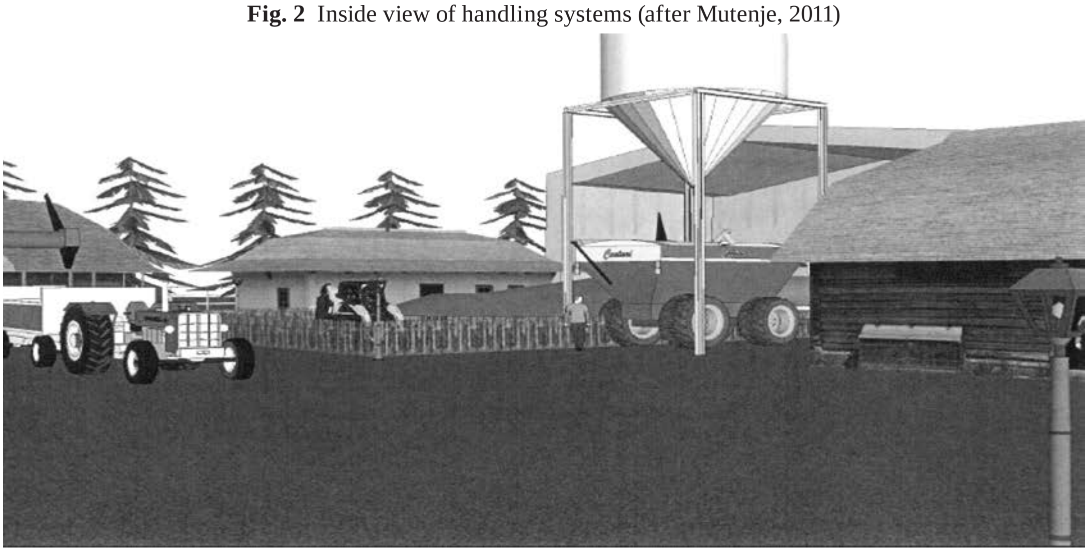


Table 1 Influence on spatial ability of VR introduction

Measurable Parameter	Details and Outcomes
Influence on spatial ability	• About 80 % of the poor performers in the pre-MRT reported their post-test scores increased by 10 % or more. • More than 68 % of the engineers reached the project's goal, improving their spatial visualization abilities and test scores by 10 % or above in the post-MRT • About one-half (53 %) of the researcher engineers increased their scores in the post-PT

Table 2 VR usability efficiency

Measurable Parameter	Details and Outcomes
Usability efficiencies	• About 92 % of the researcher engineers said that VR was fun. • More than 90 % of the engineers said that VR was not frustrating and they did not consider dropping out of the program. • 80 % research engineers agreed that VR was easy to use and very user-friendly.

Table 3 Acquisition of advanced concepts efficiencies

Measurable Parameter	Details and Outcomes
Acquisition of advanced concepts efficiencies	• About 87 % of the research engineers indicated that the VR sessions improved their abilities in systems design, graphics communication, confidence in 3-D visualization, and so on. • More than 90 % reported attainment of the advanced course objectives, such as 3-D solid modelling and visual rendering. • About 83 % of the research engineers perceived VR and the instructional materials positively.

the models and to visualize objects without physically modelling them. Other survey results concerning research engineers' spatial ability are contained in **Table 1**.

Virtual Reality Efficiencies

Efficiency in the evaluation is about efficiency in learning and teaching, including researcher engineers' perceptions or experiences with VR as an easy, fun, and motivational instruction method as well as instructors' experiences with VR as an interactive and time-efficient tool for teaching.

VR was efficient for researcher engineers' acquisition of advanced concepts or skills in system prototype development. Survey results showed that VR was an efficient instructional method to increase knowledge bases of infrastructures design among those research engineers who performed poorly by the traditional instructional method. Due to fun, non-threatening, and the interesting nature of VR, research engineers reported high achievements in mastering the advanced or difficult concepts. Survey results are as indicated in the **Tables 2** and **3**.

Generally it was hard to draw conclusions and visualize from 2D drafting drawings. When one sees a bunch of lines and hidden lines, it is hard to understand what it is. It is easier when it is actually shown as an object one could spin it and see what it is. It also helps research engineers recognize the views (front, top, right) of the agro-processing and produce handling system prototype components. VR was efficient for both male and female engineers. Female research engineers were more likely to report a lower mean than male researcher engineers in the pre-test; and were more likely to belong to the poor performer group in the pre-test than male research engineers. However, after female researchers were exposed to VR in their proceedings, they were more likely to have higher mean scores than male research engineers on the post-test. Female research engineers also responded to VR learning methods more positively and less negatively than male engineers. Both male and female researchers improved in their post-test of MRT and PT. Female researchers who performed poorly with the traditional instructional method showed greater improvement after they were exposed to VR

VR was a time-efficient instructional tool for research engineers and instructors. Instead of spending time trying to understand how parts of the handling system components interact during normal operation, the presentation of a VR prototype allows them to move their attention to later phases of the problem-solving process. Engineers commented that VR was useful to explain complex concepts to them as it enabled them to go inside, zoom in, or go through the individual components of the handling system prototype.

Also, it was time efficient for instructors. VR enhances the likelihood of interactions between demonstrators-engineers and among themselves because the instructors were able to quickly provide facilities models through VR. Thus, additional time was available. Rather than focusing on either the development of physical models or attempting to help research engineers visualize specific components of an object, instructors are able to concentrate on the learning objective and to coach in achieving this goal.

Discussion

Survey results showed that research engineers were more confident when sketching projection views of the produce handling system prototype after visualizing VR models. For the handling system prototype development process about 91 % of the research engineers expressed physical comfort in using VR; whereas, 8.6 % did not. Female researchers were more sensitive and expressed less physical comfort in VR than their male counterparts, although the difference was not statistically significant. These results will provide valuable information for future handling system prototype development VR related projects that require end-product visualisation prior to construction.

Summary

VR is a visualization tool in systems prototype development which can help research engineers and other interested parties acquire better knowledge about data or images. Many major companies or research institutions now use VR to enhance their visualization activities. It is important to use VR in design sessions, not only for enhancing visualization, but also for helping research engineers to become familiar with the important emerging technology before they enter into the thorough or detailed design sessions. As demonstrated by this project, VR technology is now readily available, both technically and financially, for infrastructures development use. This paper describes our experiences in integrating low-cost VR into agro-processing and produce handling farming system design and technical representation information sessions. The project was a collaborative effort between a several institutes of the ARC. A low-cost VR functionality requirement list, consisting of hardware and software was developed to enhance instructional delivery and research engineers' 3D visualization skills. Using the innovative tools in precision systems will also provide competitive advantages in retaining research engineers interested in design and graphics in the field, and will promote their engagement in lifelong learning, by stimulating interest in leading-edge technology.

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REFERENCES

Ausburn, L. and F. Ausburn. 2004. Desktop virtual reality: A powerful new technology for teaching research in industrial teacher education. Journal of Industrial Teacher Education. 41(4): 33-58.

Crosier, J., S. Cobb, and J. Wilson. 2000. Experimental comparison of VR with traditional teaching methods for teaching radioactivity. Journal of Education and Information Technologies 5 (4): 329-343.

Deno, J. 1995. The relationship of previous experiences to spatial visualization ability. Available at: http://www.iapsych.com/articles/kaufman2007ip.pdf. Accessed 10 February 2011.

Devon, R., R. Engel, R. Foster, D. Sathianathan, and F. Turner. 1994. The effect of solid modelling on 3d visualization skills. The Engineering Design Graphics Journal Vol. 58(2): 4-11.

Idea 21. 2010. Virtual Reality and Prototyping. Ideas21 Ltd. London EC1M 5UD, UK. Available at: http://www.ideas21.co.uk/categories/20080217_12. Accessed on 20 January 2011.

Mutenje, T. J. 2011. Integrated Agro-processing and Produce Handling Systems Prototype Design Report. ARC-IAE Reference No. 201103. Silverton, Pretoria, RSA: Agricultural Research Council —Institute for Agricultural Engineering.

Riva, G. 2003. Applications of virtual environments in medicine. Journal for Methods of Information in Medicine 42(1): 524-534.

Salzman, M., C. Dede, R. Loftin, and J. Chen. 1999. A Model for Understanding How Virtual Reality Aids Complex Conceptual Learning. George Mansion University. Northern Virginia, Washington DC., USA. Available at: http://www.virtual.gmu.edu/pdf/presence.pdf. Accessed 21 January 2011.

Sorby, S. A. 1999. Developing 3-D spatial visualization skills. Engineering Design Graphics Journal 63(2): 21-32.

Sulbaran, T. and N. Baker. 2000. Enhancing engineering education through distributed virtual reality: 2001. The 30th ASSEE/IEEE Frontiers in Education Conference.

Winn, W., H. Hoffmann, A. Hollander, K. Osberg, H. Rose, and P. Char. 1997. The effect of student construction of virtual environments on the performance of high and low- ability engineers: 2001. The meeting of the American Educational Research Association, Chicago, IL U.S.A.

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An Industry Perspective of Tractor Safety against Rollover

by
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Abstract

With the trend towards increasing mechanization overseas and the virtual saturation of the new tractor market in the industrially developing countries like India, the demand and value of the tractor operator is at its highest level. In order to obtain maximum work from the operators, it is now necessary to improve the safety and comfort of the working environment and to encourage skilled labour to stay in Farming. In India, with the increasing interest to own tractors, the current market is more than 4.5 million tractors. But, there is no definite trend in tractor industries in comparison to motor industries to promote safety and comfort features resulting in fatalities to multiply.

To gauge the impact of a ROPS (Rollover Protection Stuctures) in Indian market, a questionnaire was designed and communicated to leading tractor manufactures. The views of tractor manufacturers regarding the ROPS were upsetting. None of the industries provide ROPS particularly in Indian market while it is mandatory in developed countries. According to them, the additional cost burden could be the hindrance in popularity and acceptance in farming families. They have accepted that compulsory Government regulation may change the scenario. The absence of legislation is necessarily a favourable factor for not providing the safety features. The paper presents the status of rollover protective structures and associated constraint in Indian farming sector.

Introduction

The use of tractors in farming has revolutionized the ease at which land is prepared, crops are planted, and harvested. This widespread use of tractors has aided in economic growth and prosperity for many farmers over the years. With all of the success, the use of tractors has brought many safety hazards to the operators. Due to uneven and awkward terrain, tractors may be pushed to the limit of safe operations. Tractors used in agriculture are being produced with higher maximum design speed up to 50 km/h. In addition, suspension systems for seats, cabs and the tractor itself are becoming increasingly sophisticated thus resulting in a higher quality ride for the driver. It is reasonable to expect that tractor will be driven on highways and in the field at higher speeds in the future (Harral, 1992). Tractor are very prone to rollover on the road without a wheel trip because tractors have higher ground clearance and narrow track width and can be upset by the tire forces generated by steering maneuvers. Not much can be done except to provide protection for the driver in such accidents.

Modern production vehicles are designed to meet specific safety standards, centred on improving operator safety including seat belts, airbags, braking performance and side/frontal impact crash strength. However, these safety features are focused mainly for highway vehicles where roll over is a low occurrence incident. In contrast to such vehicles, 2 WD tractor has a much higher centre of gravity (Guzzomi *et. al.*, 2009). Combined with this, new levels of ride comfort, power, and quietness make it far easier to travel at higher speeds than the equivalent type of vehicle in the past. While hitching, tractors have a much higher risk of roll over type accidents in situations where evasive or correct steering action is needed. Added to this, the tractor's tendency to carry higher pay loads reduces the driver's ability to slow the tractor before encountering such circumstances. Therefore, the safety of tractor operator should be given prime importance in today's society with inclusion of standards, laws, court decision, human factor, function, user reaction, and sales. Attempts have been made to universally apply safety control followed by the 3 E's of safety engineering and loss control namely Engineering, Enforcement, and Education.

There are many deaths each year due to farm tractor rollovers. Due to this disturbing safety hazards, researchers and engineers have developed Roll-Over Protective structures (ROPS) for tractors and operator's safety in the event of overturns. This agricultural safety movement of the late 1950s and early 1960s thus the use of ROPS on new tractor models was initiated. Unfortunately ROPS were installed only as optional equipment for many years. Often farmers elected to use their tractors without ROPS (Harris, 2008). It has been evident from the literature that, researchers did not try for methods other than ROPS for tractor safety, barring a few. Some inventors promoted their views for a switch/device that will shut off the tractor engine at predetermined angle of tilt through which risk of overturn of tractor may reduce. But they neglected the problem created by momentum, centrifugal force and speed. This also has its inherent weakness of the limitations of human response to sudden occurrences in an arduous environment. Even mechanical intervention would not be proven so effective to avoid the rollover because tractor rollover happens within 1.5 second (Murphy, 1991) and it is little time to respond. Such hindrances has reassured the fact that safer and effective methods of prevention of injury due to rollover of tractors is the use of Roll-Over Protective Structures.

ROPS appear simple and relatively easy to make, but they must have appropriate structural strength to absorb the energy and provide protection in the specified envelope in case of an overturn. The simple roll bars on tractor appear to be built very well but itself do not suffer significant damage in the overturn. ROPS weight and its location are very important factors to consider, as they can contribute to the rollover propensity. It would seem illogical to disregard the weight of a ROPS design that ultimately increases the chance of a roll over taking place. They are not designed in the systems to suit individual tractor and built. All components are to ensure critical tolerances which are designed for a near fit and optimum protection and for maximum occupant space. Entry/exit considerations should be maximized, paramount in each design. Manufacturers design and test ROPS according to the standard, but it is not feasible for individuals to do so.

ROPS is an integral part of cabin in European countries. However, ROPS with cab is not practiced in India. It could be because of hot and humid weather of north-west part of country, where tractor's population and utilization is high (Tewari *et al.*, 2009). To avoid the same, there is need to fit an air conditioner with tractors, causing addition in cost and significant design modification. This coupled with the absence of any legislation for using ROPS has practically made this protective structure as non-existent in the Country.

In Indian tractor industry, no such research work has been reported to investigate suitability of ROPS loading on tractors. (The authors should refer to the ASABE Standard S 383). This is primarily because of the non-awareness of the utility and requirement of ROPS. It was also seen that tractor industries do not have any accidental record system by which they can get feedback to minimize the safety hazard. The industry is keen to get market profit of tractor where the moral responsibility of saving a life is ignored. They are selling millions of tractors without ROPS in Indian market where it is not mandatory by regulation but they have to fit ROPS in those countries where legislation enforced him to provide protective structure. Self-made rollbars are often thought to be better than nothing for overturn protection. However, without testing, the adequacy of a self-made rollbar is questionable. Due to complexities in design and testing, it is recommended that ROPS be built only by manufacturers who can ensure that standard requirements are met.

Rops and its Efficacy

ROPS, Roll-Over Protective Structure, is a reinforcement member(s) installed in to, or on to a tractor with the intention of protecting or limiting the degree of rollover thereby reducing damage to the tractor and preventing operators from being knocked out and crushed. The primary function of such structures is to ensure the highest possible level of passive safety for operators which reduce the risk of head, neck/spinal and upper torso injuries, ultimately preventing death. It should be clear that ROPS will not protect tractor rollover; it will save the operator from getting crushed.

There are three basic types of ROPS namely, skeleton frame, frame with overhead roof, and enclosed cab. Some ROPS frames and enclosed cabs are equipped with overhead canopies to protect the operator from falling objects. Canopies that protect against falling object are called as FOPS (Falling Object Protective Structures). Such canopies are recommended when using front-end loaders, working in the woods or in other circumstances where falling objects may be a hazard. Canopy structures is FOPS not ROPS. ROPS are also classified based on numbers of supporting roll bars or posts. If two posts are supporting overhead projection than it's called '2 post (2P) ROPS'. Such types of ROPS are common in low and medium horse power segments of tractors, lawn mower and other self propelled machinery. In case, the operator sitting area is protected by four roll bars then it is called as 4P-ROPS. ROPS may also be classified as per their locations on the vehicles namely, internal or external (Brown & Davis, 1999). Internal ROPS are designed to fit inside the cabin space of the vehicle mounting to its floor pan. It suits to all vehicle types; wagon, utility, bus and supports original roof structure. These type of structure needs less mass for a stronger structure and have less effected by height of centre of gravity (CG). On the other hand, the external types are designed to fit around the outside of the vehicle cabin mounting to the chassis rails under the vehicle, or behind the cabin as part of the rear tray sometimes extending over the cabin roof. Etherton *et al.* (2007) have defined an automatically deploying, telescoping ROPS which has been developed to address the issue of low clearance situations.

To suggest ways of preventing accidents, data were collected and analyzed from tractor overturns in Nebraska from January 1, 1966 to January 1, 1972. There were 175 accidents investigated during this time, and 78 of the accidents resulted in a fatality. It should be noted that, of the 175 tractors involved in the accidents, only 8 were equipped with protective roll bar and seat belt. Of these 8 tractors, no fatalities occurred in these accidents, and 4 of these 8 accidents resulted in no injuries. This data gave credible evidence that implementing protecting structures on tractors would help save lives (Springfeldt *et al.*, 1998). The latest figures from the NIOSH suggest that there are approximately 250 tractor rollover fatalities per year in United States. Out of the 4.7 million tractors in use on U.S. farms, one-half of them are without rollover protection. Colorado State University revealed that 29 % of the deaths were tractor related in which farmers were killed by rollovers.

Introduction of ROPS has led to reduction in fatalities of tractor accidents all over the world. In countries that introduced mandatory regulations long ago an evident decrease in the number of rollover injuries is reported. Obligatory regulations for new tractors were introduced in Sweden in 1959, Denmark 1967, Finland 1969, West Germany, Great Britain, and New Zealand in 1970, the United States 1972, Spain 1975, Norway 1977, and in Switzerland 1978. In most countries the safety rules extended to old tractors also, but were not always mandatory. In Canada and Australia federal authorities have no regulations at all concerning to ROPS on tractors (Springfeldt, 1996). (In Canada, there is a regulation that no tractor can be sold without ROPs and older tractors must be retrofitted with ROPS if operated for any task.)

The frequency of fatal rollovers per 100,000 tractors per year has been reduced from 17 to 0.3 since mandatory regulations were introduced in Sweden. In Norway the frequency has decreased from 24 to 4 between the periods 1961-69 and 1979-86 and in Finland from 16 to 9 from 1980 to 1987. From 1961 to 1986, the West German rate has been reduced from 6.7 to 1.3. In New Zealand the risk has decreased from 37 to 30 from the period 1949-58 to the period 1969-74 (Springfeldt, 1996).

Current Situation of Tractor Safety in India

The global spotlight on tractor manufacturing in terms of unit volume seems to be swinging away from USA and Europe towards India, where growth in the number of producers and total volume of agricultural machinery production in recent years has been remarkable. The Indian tractor industry is being the largest in the world, accounting for one third of the global production. In 1971-72, tractors had a share of 7.5 % in terms of the use of power tools in agriculture. At present, this accounts for 42 % of the total share of mechanical power used. Tractor density in India is 12 tractors per 1,000 hectares whereas world average is 17 tractors per 1,000 hectares while in US, it is 27 (Tewari *et al.*, 2009).

Literatures on tractor accident analyses are found available only to United States of America and Europe and very limited information is available for the rest of the world and few research work has been reported for Indian tractors, which in fact is the need of the day.

In Indian context, it was seen that of the total accidents, 30.5 % were due to farm machines, 34.2 % due to hand tools and 35.3 % accidents were due to other sources like snake bites, animal bites, fall in well, lightening, heat stroke etc. The overall accident incidence rate per year was 333 accidents per 100,000 workers whereas the fatality rate per year was 18.3 per 100,000 workers (Gite, 2010). Source wise and severity wise distribution of farm machinery accident indicated that highest number of accidents were due to tractor and tractor operated implement (31 %) followed by animal drawn implements (22 %), threshers (14 %), electric motor/pump sets (12 %), chaff cutters (9 %), power tillers (6 %), sprayer (4 %) and other machines (2 %). Tractors and tractor operated implements were responsible for 44 % of the total fatalities. Therefore, the machines which need immediate attention are tractors. Hence this puts forward a serious look for countering the situation for the Country.

Industry Contribution towards Operators' Safety:

Most of tractor manufacturers do not provide ROPS in India and neighbouring countries but they insist for ROPS in countries where it is mandatory. One of the Tractor companies, for instance, has a special category identified as 'E mark' where ROPS are part of the assembly, but intended only for export market. Some manufactures are providing a rigid structure as a canopy support. By visual observation, it could be categorized as a kind of rollover protection device, but there is no certification of testing authorities. Because of the size, utility, and relative cost of gray market Asian tractors are attractive to rural landowners, resulting more non-ROPS tractors.

Methodos

Studies conducted in various countries have shown that provision of safety gadgets along with regulations has resulted in reduction of agricultural accidents considerably. The knowledge available with regard to safety features in Indian market is not known. To gauge the impact of a ROPS in Indian market, a questionnaire was designed and communicated to leading tractor manufactures. There are numbers of tractors manufactures in India namely, Heavy Machine Tool Ltd. (HMT), Tractor and Farm Equipment Pvt. Ltd. (TAFE), John Deere Pvt Ltd (JDPL), Mahindra & Mahindra (M&M), Eicher Motors, Bajaj Tempo, Punjab Tractor Limited (PTL), New Holland, Indo-Farm Equipment Ltd., Sonalika tractors Ltd, SAME tractor Ltd, Preet tractors and other. Out of these industries, some industries had shown interest in the study and came forward to discuss this critical issue. Proposed questionnaire was to quantify the need of tractor cabs and ROPS both. Within a prescribed time, five tractors manufacturers responded

Table 1 Feedback of Tractors Manufacturers in regards to ROPS

Questions	Tractor Manufacturers				
	1	2	3	4	5
Production per year	25000	80000	30000	1200	50000
Country sale, (%)	50	23	8.2	95	Not reported
Export sale, (%)	50	18	1.7	Nil	
Market share, (%)	5	22	8.2	5	13.6
Popular model (BHP)	45	35, 40	30, 35	35	35, 40
Do you manufacture ROPS?					
a) Yes	-	-	*	-	-
b) No	-	-	-	-	*
c) Outsource	*	*	-	*	-
Have you provided ROPS in export model	*	*	*	*	*
Reason for not providing ROPS					
a) Design modification	*	*	*	-	-
b) Axle housing failure	-	-	-	*	*
c) Higher cost	-	-	-	-	-
Reason for not using ROPS					
a) Cost	-	*	*	-	*
b) Non-awareness	-	-	-	*	-
c) Social constraints	-	-	-	-	-
d) Any other, specify	Regulation	-	-	-	-
Which type of ROPS suitable for Indian tractor?					
a) Two post ROPS	*	*	*	*	*
b) Four post ROPS	-	-	-	-	-
ROPS on tractors will lead to problem of					
a) Vibration and backward visibility	-	-	*	*	-
b) Reduce the life of axle housing	*	*	-	-	*
c) Interruption in field operation	-	-	-	-	-
d) Any other, specify	-	-	-	-	-
Effect on marketability?					
a) Increase	*	-	*	-	-
b) Decrease	-	-	-	-	-
c) No effect	-	*	-	*	*
Is Government regulation necessary?	*	*	*	*	*
Are you convinced ROPS saves lives?	*	*	*	*	*
Need of tractor ROPS?	*	*	*	*	*

well and sent back the filled Performa as presented in **Table 1**. Whereas other manufacturers were requested again to send the filled questionnaire, but in absence of feedback from them required details has been gathered through dealer points and marketing officials of particular company. This information was for enhancing the knowledge base of Indian perspective and is not produced in this paper.

Another dealer's point survey (**Table 2**) has been carried out to know the real aspect of ROPS fixing. This survey was also linked through progressive farmers, sales man of tractors, village representative and policy makers etc. The main aim of survey was to find out the geometrical variation in axle housing but later on strength and standardization part was also taken under due consideration. The upshots of this survey were discussed under results and discussion.

Table 2 Performa to be filled at dealer point for categorization of axle housing of agricultural tractors

Personal details	
1.	Name of owner
2.	Name of Firm
3.	Company represented
4.	Communication address and seal
Business details	
1.	No. of models available
2.	Name of models
3.	Models at show room
4.	Average tractor market in area
5.	Average no. of tractor sold per year
6.	Mostly liked HP range
7.	Model liked by dealer and sale
8.	Model liked by farmer and sale
9.	Which model do you recommended to farmer
Technical details	
1.	Any rigid structure like canopy support or ROPS fitted in any model of tractor
2.	If yes, specify the model and fitting location
3.	Any failure reported due to presence of same structure. if yes, specify the details.
4.	Design of rear axle housing in view of Fender attachment (center to center distance), Shape of housing
5.	Type of braking system
6.	Is common housing used for particular braking system
7.	Photograph of model
8.	Part drawing from catalogue
9.	Is any canopy support fitted with axle housing, specify location.
10.	Any failure reported in housing due accident/overturn etc.
11.	Reason for variation in axle housing
12.	Type of axle housing present
13.	General material used for axle housing casting
14.	Any change in material after visual observation
Other Information	
1.	Any tractor accident found in your area
2.	Reason of accidents
3.	List of damage part repaired

Results and Discussion

Output of Questionnaire

The views of tractor manufacturers regarding the ROPS were upsetting. None of the manufacturers provide ROPS particularly in Indian market. A general agreement was seen to provide protection against rollover and environmental conditions. The additional cost burden in fitting ROPS was put forward as the main reason as it would be hardly acceptable in Indian farming families. The absence of legislation is necessarily a favourable factor for not providing this safety features. Manufactures are ready to supply tractors with ROPS fitted once the regulation has been implemented. Manufacturer's pointed out that Indian farmer are not aware with the necessity of ROPS and due to absence of mandatory regulation, industries are not forced to supply ROPS in the market. The survey revealed that ROPS systems are not commercially available in India and no government regulations are in existence to implement ROPS to saturate the tractor fleet in India. Some subjective question has also been asked from the industry to look into the seriousness of matter. Industries have responded positively in this segment of questions. Due to company's policies, identity of each industry has been sealed and presented in the name of manufacture 1, 2 and so on. Few answers of these questions are presented below.

Q.1- *Do you support the idea of cost a effective cabs and ROPS for tractors in India. What is your view in this regard?*

Response:

Manufacturer 1: Yes, an affordable design for Indian customer should be worked out.

Manufacturer 2: Yes

Manufacturer 3: Yes we subscribe to the idea of low cost cab. Cab will increase operator safety and comfort; it will also reduce noise at OEL. However we feel cost is major block in sale of cab mounted tractors.

Manufacturer 4: Yes. The cost effective cabs and ROPS will definitely accepted by operator.

Manufacturer 5: Yes, A standard must come out to define minimum cross section and designing technique.

Q.2- *Are you planning for any additional safety feature in your future models of tractors? Indicate the relevance.*

Response:

Manufacturer 1: We have in our export tractors, we do provide operator's safety in our all design, ROPS can be provided if govt. comes with regulation and make mandatory for all tractor manufactures. Our tractors are design to adopt ROPS needed.

Manufacturer 2: Safety seat belt with ROPS

Manufacturer 3: Safe starting device to avoid starting of tractor while gear is engaged. PTO guard to avoid injuring to operator. Spark arrester to avoid any husks other material to catch fire.

Manufacturer 4: Our few models are under test at CFMTTI, Budni. We shall incorporate their recommendation on regular production.

Manufacturer 5: ROPS with seat belt has been initiated in few higher HP models. NSS, spark arrester, cab etc will be added further. Additional Cost is major hinder to provide the same.

Q.3- *Would you like to assist us in developing in new economic cab and ROPS for Indian tractor?*

Response:

Manufacturer 1: No response

Manufacturer 2: We don't have any such plan at present

Manufacturer 3: Yes. We can enter into a contact for development of cab which would include design, testing, validation and development of cabin.

Manufacturer 4: No

Manufacturer 5: Yes, a time bounded project may be carried to solve this serious issue with Institute and Industrial cooperation. We welcome your proposal.

Hence it may be concluded that it is not the availability alone that restricts the ROPS on tractors. Of course, the absence of Govt. Regulation, the socio-economic factors, all lead to operator's unsafe situation with tractor. The industry is eyed only to the market profit of tractor where the moral responsibility of saving a life is ignored. It is hysterical to accept the fact that even life of a person is protected only when it is abided by a law. A regulation is expected by the year 2011 with regard to ROPS in India, but that again will be concerned to new tractors. Here, the older ones, which are currently in farm, will be left unprotected.

Fig. 1 Variation in available safety frame for different Indian tractors

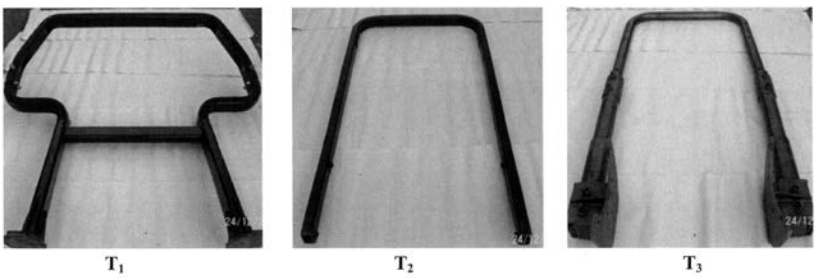


Fig. 2 Geometrical variation in available axle housing of different Indian tractors

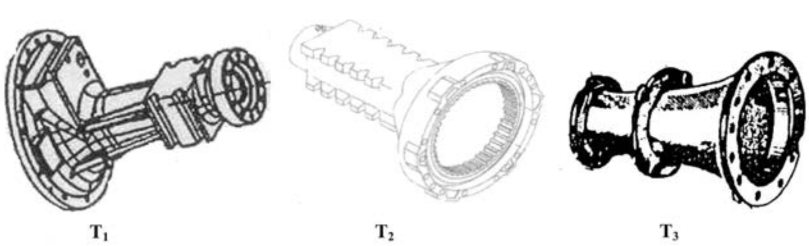
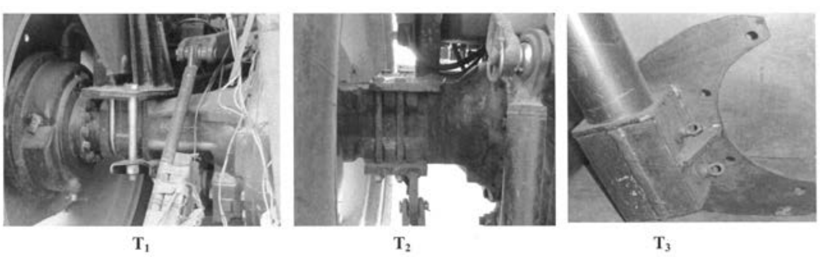


Fig. 3 Fitment technique of different safety frame on axle housing



Outcome of Survey

Variation in safety frame of Indian Tractors

On the basis of the response got from questionnaire, available safety frame of tractors were studied. Although the visual concept was similar, each ROPS was varying greatly in size/shape and mounting locations. It was seen that three tractor models of different manufacturer was available with such frames and the same were taken for studies shown in **Fig. 1**. Indian tractor manufactures keep these safety frames under the category of canopy support in their parts catalogue. This practice allows them to provide such part in case of demand only for specific model. **Fig. 1** to **Fig. 3** is giving an overlook of ROPS design with respect axle housing and fitment technique. An important point has been noticed that all the structures were stout and rigid which could withstand against rollover impact energy but there was no provision or availability of seat belts. This revealed that frame has no use except supporting the canopy.

Frame 1

This structure was available with one of the leading companies in India and marketing different models under different brand names. The attached protective structure has been provided with an aesthetic look to match with the appearance of tractor. The frame structure was hollow tube with rectangular cross section of 50×100 mm^2 with thickness of 5 mm. The height and width of structure was observed 1,600 mm and 1,340 mm respectively. Frame width over the axle housing was seen 720 mm and it was projected to outside upto track width over the seat which provide the ample space for operator movement.

Frame 2

This frame is available with subsidiary company in India. It manufactures a Series of agricultural tractors and has secured ISO 9001 : 2000 certificates for its compliance to quality systems. In regard to operator safety, tractor is fitted with canopy support have rectangular cross section of 40×60 mm^2. The height and width of structure is 1,450 mm and 750 mm respectively and well supported by fenders. The attached frame was very light in weight. So, safety against rollover by this frame is questionable.

Frame 3

This frame was available with Government regulated company of India. It has been providing protective structure with 50hp model in Indian market. This structure is also equipped with canopy hood (FOPS) to protect operator from falling object, rain and heat. Frame was made of hollow circular tubing section of diameter 90-60 mm with thickness 5 mm. It was a telescopic type structure to operate in low clearance and orchard situation. The height and width of structure was found 1,760 mm and 790 mm respectively. There was no adjustment for changing width and mounting attachment was half circular in shape, which could be able to attach on round axle housing only. The fitted structure was located well behind the operator seat and expected that it will not extrude in operator zone during rollover.

Frame 4

Although aforesaid safety frame are available for Indian tractors without certification, these are specific to manufactures only. Hercules ROPS, a leading International one, would be ideal for comparison. Hercules Company has its own workshop and they are manufacturing ROPS for all market tractors, independent to its manufactures. Their ROPS has adjustability in width to suit variety of models which have difference in fender width. Frames are consist of three member i.e. two vertical and one horizontal post. Horizontal member has slot arrangement for fixing vertical post by which overall width can be easily adjusted to suit different models. Cross section of all three post was 50×100 mm^2 with thickness 5 mm. This ROPS can accommodate the range with of 660-1,080 mm and overall height and width was found 1,800 mm 1,350 mm respectively.

Seat belt

It is safety critical items for the passenger in case of sudden acceleration/deceleration and accidents. Seat belts are integral and compulsory parts of ROPS. It was estimated that ROPS saves life if seat belt is used otherwise ROPS has no use. Presently there are Indian standards and CMVR covering the seats and related items. AISC also identified these as one of the priority items and a series of standards are being drafted by a Panel. Seat belts have become mandatory fitment on front seats of M and N categories of vehicles from April 1994 in India. Even though there is a safety standard covering some of the requirements of safety belts, manufacturers are not in line with international requirements. Hence, it is necessary to have a comprehensive standard for safety belt. It was said before that aforesaid safety frame could be act as ROPS but all frames are not available with any seat belt which is questionable whether frames provided for rollover safety or just over designed the canopy support.

Difference in axle housing

Attachment of 2-Post ROPS is subjected to axle housing design only. Since many tractor models do not have square or hexagonal axle housing, they cannot use a standard compression-fitted mounting structure. So, a hurdle to ROPS fitting is the design of axle housings itself, some of them are shown in **Fig. 2**. These are some axle housings sketches of leading tractor manufactures and their respective models are mostly liked by the farmers. Retrofitting of ROPS on different models is a challenge in view of the axle top, fender design and strength criterion. Existing housing have opening for fixing the fenders with help of bolts. This is only the place where ROPS can be attached otherwise some extra flat plate should be fixed with ROPS bottom that would be gripped by the housing. Welding on housing to fit ROPS may not be advisable because high temperature of welding may disturb the chemical composition of the casting material and sometimes it may burst too. Tractor manufacturers are building engine and major parts at company workshop floor except few. Many parts like axle housing, gears box, brake backing plates, mounting flanges, spring mounting plates, and accessory units, that may be riveted, welded or cast, are outsourced to local traders. Manufacturers provide design of particular parts to trader and they produce the same in mass production. Testing and verification of supplied material is subjected to manufacturer only, as parts found defected go back to vendors for desired modification. This practice results in variety of model produced in each HP segment categories of different brands. Hence, several designs of axle housing exist and they even keep on changing at regular intervals due to competitiveness in the market to slow down the cost and material. A major constraint in ROPS fixing arises here.

Using low grade iron

Johnson and Ayer (1994) investigated that company had designed, built and installed a ROPS structure on a particular tractor model. As they have conducted the test, tractor front end rose up and the ROPS frame impacted the ground as intended, however, the axle housings of the tractor failed catastrophically. The test dummy in the seat was crushed clearly to the point where if it had been a field overturns with an operator. Zhifeng and Paul (1997) stated that pre-ROPS (before ROPS were available) tractor axle housings were not designed to support the ROPS. For their suitability for accepting reliable ROPS, strength test was carried out of pre-ROPS tractor axle housings. The results showed that some pre-ROPS axle housing can successfully support the ROPS with a safety factor of about two while others have less safety margin. Job (2008) was of the opinion that some tractor designs were not capable of ROPS installation. Catastrophic failures of axle housing occurred all too often.

In India, tractor axle housing is usually made of cast iron and according to IS: 6331,1987 (reaffirmed 2005), there are five grades of automotive Indian iron for casting namely FG150, FG200, FG260, FG300, and FG350. Generally, tractor manufacturers used FG260 grade with 0.5 % copper while in automotive industry FG300 is common. Alloying elements such as chromium, copper, nickel, tin, molybdenum or other elements may be employed to meet the specified hardness. It is thought that axle housing of tractor is strong enough to support ROPS loading with hold to fenders. Some field experiences revealed that axle housing failed to support the protective structure and estimated that mounting technique was not appropriate. Casting material of housing could withstand at high compressive force but, may fail by impact loading. Therefore, investigation on this aspect needs to be done.

Model depended

(describe the **Fig. 3**)

Each model of tractor workspace can be vastly different (Shrivastava *et. al*. 2010) and also in terms of wheelbase, fenders location and fitting style as shown in **Fig. 3**. It is important to assess and design a specific solution to each model, rather than a 'generic' design applied to all. Moreover, mass differences do exist in most of the tractor models which makes it practically impossible to go for a universal ROPS design. Companies have different models in each HP segment and every model has separate mass of each tractor. The reference mass of tractor has direct relation to weight of ROPS system. If a ROPS do mount on other than designed model then it could break the axle housing. Some Industry has provided ROPS on higher HP model but the same cannot be fitted on medium HP models. Energy absorbed by the higher HP model due to higher weight will be comparatively more with regard to medium HP model. This effects the ROPS design feature and its weight that do not allow to mount ROPS on other than designed model.

Ashburner (1972) stated that rollover propensity is an issue which has been litigated extensively but is not regulated. Manufacturers have defended poor designs on the basis of theories about performance requirements for the types of vehicles involved. The theories prove to be all false, and not that difficult to refute. It is revealed from literature that narrower the track width of the tractor greater the chances of a rollover accident occurring due to higher CG. Although tractors are designed to travel no faster than 30km/h on public roads, but significant number of instances were found in which the forward speed at overturn was in excess of 40km/h. Harral (1992) estimated that 58 % overturn happened at speed below 10 km/h by modern tractor. Normally, the weight distribution ratio on front and rear wheel is 1/3 and 2/3 of tractor mass respectively in India and having additional mass in the form of ROPS at rear on the tractor, will result in a higher propensity to rollover. It would be suicidal to provide type of ROPS structure that gives the tractor a higher propensity to rollover, which actually may not happen otherwise. Hence, legal certification in this regard is essential.

Adoption of legislation

European and US countries have well establish procedure for agricultural accidents record to overview the safety hazard. Agencies like NIOSH, HSE etc. are continuously looking into safety and comfort of worker. There are mandatory laws to provide safer environment for industrial worker and these law constantly enforced by the law making agencies (SAE J2194). In India, regulations are being implemented by legislative but these laws are not forced to adopt, particularly in operator safety concern. Some industries like TATA Steel, SAIL have come forward to provide safer environment for their worker with short term courses organised by leading Technological Institutes in India. But, the safety in Agricultural industry is still missing. A number of regulations are in existence but lack of enforcement rends hazardous situations. Dangerous Machine Act (DMA) has been implemented but identified machinery under this act are very few. Standard has been developed for ROPS testing (IS: 11821) but no regulations have come for ROPS implementation and fitment on tractors. Indian Council of Agricultural Research (ICAR) has come up with issue of agricultural accidents and operator death, and emphasizing tractor industries on fitting ROPS on all of tractor models.

Conclusions and Recommendations

Current trends focus towards increasing farm mechanization in developing countries. Some investigation found that older tractors are not meant for fixing ROPS, because tractor axle housings were not designed to support the ROPS. Several designs of axle housing exist which the major constraint in ROPS is retrofitting. Moreover, mass differences do exist in most of the tractor models which makes it practically difficult to go for a universal ROPS design for all tractors. Tractor manufacturers using FG260 grade material for axle housing while in automotive industry FG300 and FG350 is common. Standard has been developed for ROPS testing but no regulation on ROPS implementation on tractor. Due to this, tractors are continue to causing fatalities. For these tractors, the only safe options may be recycling the tractor, or making it a stationary power source.

Therefore, it is recommended that before implementing the strategies, researcher have to look into the actual problem associated with design because faulty design may abused by the user in the field and if something is harmed to the user on ground then it would will not be going to accepted in future also. Engineering aspect of ROPS retrofitting revealed that variation in shape and size of axle housing, ROPS design feature and strength criteria of housing is major lacuna for non availability of ROPS. A well-engineered suitable mounting base or fixture could be the answer for the same. The mass variation in medium HP for all makes is significant but energy dissipation may be reduced by suitable mounting bracket. So, there is a need of proper implementation of engineered mounting fixture which will reduce the high number of annual fatalities due to tractor overturn.

REFERENCE

ASAE S383.1. 2004. Roll-Over Protective Structure (ROPS) for wheeled Agricultural Tractors. American Society of Agricultural and Biological Engineers.

Ashburner, Edward John. 1972. An investigation into aspect of the design and testing of tractor safety frame and cabs. Ph.D. thesis. University of Reading. West Wetherby, UK.

Brown, Davis. Rollover protection structure for mining. Online access on 17/9/2009, http://www.minigroups.co.au/tech.htm

Etherton, John R., Ronaghi Mahmood, and S. Current Richard. 2007. Development of a pultruded FRP composite material ROPS for farm tractors. Composite Structures 78: 162-169.

Guzzomi, A. L., V. Rondelli, A. Guarnieri, G. Molari, and P. G. Molari. 2009. Available energy during the rollover of narrow-track wheeled agricultural tractors. online access, www.elsevier.com

Harral, B. B. 1992. ROPS test criteria for 40km/h Agricultural and forestry tractors. HSE contract Research Report No. 44/1992. Silsoe Research Institute, Wrest park, Silsoe, Bedford.

Harris, James R. 2008. Predicting the performance characteristics of assembled rollover protective structure designs for tractors. Ph. D thesis. College of Engineering and Mineral resources at West Virginia University. Morgantown, West Virginia.

IS: 11821 1992. Method of test and acceptance conditions for protective structures of Agricultural tractors (part2).

IS: 6331 1987. Specification for Automotive grey Iron casting, edition 2.1.

Job, Richard W. 2008. Roll-Over Protective Structure Development; an Industry Perspective. ASABE Annual International Meeting. Rhode Island Convention Center. June 29-July 2.

Johnson, C. M. and P. D. Ayers. 1994. Testing of roll-over protective structures (ROPS) designed for pre-ROPS tractors. In Proc.of International Summer Meeting, Paper No. 94-5003. Kansas City, Missouri, 19-22 June.

Murphy, Dennis J. 1991. Tractor overturns hazards. Pennsylvania state University fact sheet Safety-34, Pennsylvania cooperative extension.

SAE J2194 AUG2002. Roll-Over protective structures (ROPS) for wheeled agricultural tractors.

Shrivastava, Ashish K., C. R. Mehta, M. M. Pandey, and Atul K. Shrivastava. 2010. Accessibility index of Indian tractors. Agricultural Mechanization in Asia, Africa and Latin America (AMA). Vol.41(3): pp. 17-20.

Springfeldt, Bengt. 1996. Rollover of tractors —international experiences. Safety Science, Vol. 24(2): 95-110.

Springfeldt, B., J. Thorson, and B. C. Lee. 1998. Sweden's thirty-year experience with tractor rollovers. Journal of Agricultural Safety and Health, 4, (3): 173-180.

Tewari, V. K., Shrivastava Ashish Kr, K. P. Vidhu. 2009. Investigation on Safety Features, Accidents and Standards in Tractors and Machinery in India. Presented during IEA conference, Beijing, China.

Zhifeng, Li BS and Paul D. Ayers. 1997. Strength Test for Pre-ROPS Tractor Axle Housing. Journal of Agromedicine, 4,3/4: 303-307. ISSN: 1059-924X.

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Mathematical Model for Design and Development of Double Drum Rotary Screen Cleaner-cum-grader for Cumin Seed

by

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Abstract

The cleaner-cum-grader designed and developed was found suitable for cleaning the cumin seed from fine impurities and other foreign matter. For getting higher cleaning efficiency and therefore, more pure grades, the machine should be operated at slow speed and at low inclination while maintaining a controlled feed rate. At about 11 rpm rotational speed of the screen and with 5 % inclination and 30 kg/h feed rate, the machine has given higher cleaning efficiency above 82 %. The efficiency above 80 % level could be obtained if the machine was operated at 11 rpm screen speed and 5-7 % slope and 30-50 kg/h feed rate. By adjusting the speed, slope and feed rate appropriately as indicated above, the desired level of cleaning and grading of the cumin seed can be achieved.

Introduction

Agriculture is the largest single industry in the world and seed production is the important segment of this industry. Grain as it comes from the field, contains contaminants and foreign matter like weed seeds, stem, leaves, broken seeds, stones, dirt etc. These contaminants must be removed and the cleaned grain properly handled and stored to provide high quality of material and extend storage life of the product. Cumin seeds are largely used as condiments for many food items and form essential ingredients in all mixed spices and curry powders. It is also used in medicine, cheese and as flavor in bread, cake and pastries. Cumin seeds being light in weight and with rough surface are difficult to clean and grade by the traditional method using vibratory screen or reciprocatory screen. Taking above point into mind a mechanical cleaner-cum-grader for cumin seed was developed for improving cleaning efficiency.

Review of Literature

Birewar, B. R. and S. C. Kanjilal, (1982) designed and developed a hand operated grain cleaner of 100 kg/h capacity at the Indian Grain Storage Institute, Hapur. They indicated that the device was suitable for cleaning of wheat and paddy and also found efficient as compared with conventional type sieve.

Bisht, B. S. and L. K. Sinha, (1985) tested an air screen seed cleaner-cum-grader for wheat. Effect of feed rate and air flow rate at feed section as well as lifter screen section was measured and correlated with final seed purity and power requirements. It was observed that the seed purity was maximum when the machine was operated at 700-1000 kg/h with air velocities of 15-16 and 5-6 m/s.

Kachru, R. P. and K. M. Sahay, (1988) reported that grain cleaned at farm level would fetch an extra value of Rs 250-400/ton. They also concluded that the commercial type cleaners available in the market were of large capacity and high cost.

Kachru, R. P. and K. M. Sahay, (1990) tested a medium capacity grain cleaner for wheat, soybean and chickpea. The capacity of the cleaner varied between 350-600 kg/h and 500-900 kg/h for pedal and power operated respectively. The maximum purity of separated grain achieved was 99.9 % for chickpea in pedal operated where as 99.9 % for soybean in power operated.

Kathiravan, M. et al. (2008). Delinted cotton seeds of MCU 12 and Surabi cultivars were graded using lab model two screen cleaner cum grader in order to find out optimum sieve size for maximum recovery and seed quality. Decrease in sieve aperture size (4.5 mm) yielded high recovery in both cultivars (94.40 and 94.15 %, respectively). Significant differences were observed in physical measurements of seed samples collected during grading in both cultivars. Among the different sieve sizes, 4.5 mm diameter sieve was suitable for both cultivars to obtain good recovery and

Saurabh, P. (1990) developed a cleaner-cum-grader suitable for spices like cumin seed, funnel seed etc. having vibratory screen. He reported optimal values of different parameters of the machine such as deck angle: 12 ± 30, residence time: 30 seconds, air velocity: 5.2 m/s.

Singh, N. K. et al. (1980) developed a rotary screen pre cleaner for both paddy and wheat with an output of 9 and 5 t/h with cleaning efficiency of 95 % at screen speed of 20 rpm.

Vishwanathan, R. et al. (1994) developed rotary sieve type cleaner-cum-grader suitable for removing all small and large size impurities. The capacity of the unit was 125 kg/h and effectiveness was 71 %.

Experimental Setup

Machine factors

The machine capacity, feed rate, screen size, operating characteristics, angle of inclination, speed of rotation etc. are some of the important machine parameters which would influence the design requirements for a grain cleaner. A material should spread uniformly over the full width of the screen surface. The size of the screen surface is dictated by the capacity requirement of the machine. The shape of the opening depends upon the shape of the grain is to be handled.

Mathematical Model of Rotary Cleaner

The nature of the motion of the grain over the surface of the cylindrical sieve depends upon the coefficient of friction on the give surface, the kinematic operating conditions of the sieve and the critical condition. **Fig. 1** describes the force acting on the grain in a rotating cylinder. The kinematic condition is governed by centripetal acceleration $r^{\omega 2}$, initial condition of the particle, and the point at which they are delivered on to the sieve surface and their initial velocity. The release of fine grains in a cylinder sieve depends on their relative velocity and force acting on them. These forces are the weight of the particle mg, the centrifugal force $mr\omega^2$, the normal reaction of the sieve surface N and the friction force F, which is given below;

$$F = N \tan \varphi \quad \text{.............................. (1)}$$

If the grains located in quadrant I or II in Figure 1, then the condition for sliding over the sieve is;

$$mg \sin \alpha > F \quad \text{............................ (2)}$$

Substituting the value of F in **Eqn. 2**, we get

$$mg \sin \alpha > \tan \varphi \,(mg \cos \alpha + m\, r\, \omega^2)$$

From which we get;

$$g \sin (\alpha - \varphi) > r\, \omega^2 \sin \varphi$$

or

$$\sin (\alpha - \varphi) / \sin \varphi > r\omega^2 / g = k \quad \text{.. (3)}$$

Since the maximum value of $\sin (\alpha - \varphi) = 1$, the condition for the grain to slide is given by;

$$\frac{1}{\sin \phi} > K \quad \text{.................................... (4)}$$

The limiting value of the kinematic index K_1 at which a grain is at rest relative to the sieve surface and move together with it is;

$$K_1 = \frac{1}{\sin \phi} \quad \text{............................ (5)}$$

The critical angular velocity of the cylindrical sieve at which grains do not slide and consequently the sieving of fine particles ceases is;

$$W_{cr} = \sqrt{\frac{g}{r \sin \phi}} \quad \text{.......................... (6)}$$

The actual velocity of the cylindrical sieve must be less than critical, that is;

$$W_{act} = W_{cr}$$

The limiting angle through which the grains rise along with the sieve surface after which they slide back in quadrant I and II is determined by the condition given in **Eqn. 3**;

$$\alpha - \varphi > \sin^{-1} (K \sin \varphi)$$

From which we get,

$$\alpha > \varphi + \sin^{-1} (K \sin \varphi)$$

Since $\sin^{-1} (K \sin \varphi)$ cannot be greater than $\Pi/2$, $\alpha_1 = \Pi/2 + \varphi$. Hence K is less than K_1 grains ascending with the cylindrical sieve surface without sliding over it can not go above α^2 since, the grains begins to slide back and the fine constituent are sieved out through the openings. When the grains are in quadrant III and IV, the condition of the grains to slide back is described by;

$$m\, g \sin\theta > F$$

Subsituting the value of F and rearrange then;

$$\frac{\sin(\theta + \phi)}{\sin \phi} > \frac{r\,\omega^2}{g} = K_1 \quad \text{.............. (7)}$$

The differential equation for the absolute velocity of grain while sliding downward over the inner surface of a cylinder in the natural coordinate system then;

$$m\,(dv / dt) = mg \sin \alpha - \tan \varphi\, N$$

Since

$$dv / dt = [d\,(rd / dt)] / dt = r\,\ddot{\alpha}$$

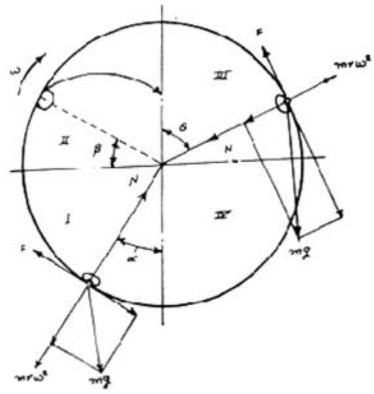
and

$$N = m\, r\, \dot{\alpha}^2 + m\, g \cos \alpha$$

The equation of motion of grain becomes;

$$m r \ddot{\alpha} = m g \sin\phi - \tan\phi\, m r\, \dot{\alpha}^2$$

Fig. 1 Force acting on the grain in a rotating cylinder



$- \tan\phi \, mg \cos\alpha$

or

$\ddot{\alpha} + \tan\phi \, \dot{\alpha}^2 = (g/r)\sin(\alpha - \phi)$

$/ \cos\phi$ ....(8)

If it is further assumed that;

$\dot{\alpha} = \sqrt{z}$ and $\ddot{\alpha} = (1/2)(dz/d)$

we have the liner equation

$\dot{z} + p(\alpha) z = q(\alpha)$......................(9)

Where

$p(\alpha) = 2\tan\phi = \tan\in$ *and* $q(\alpha) = 2g\sin(\alpha - \phi)/ r\cos\phi$

The solution of **Eqn. 9** is;

$$z = \dot{\alpha}^2 = \frac{2g\cos\in}{r\cos\phi}\cos(\alpha - \phi - \in) + e^{-2\alpha\tan\phi}$$

At the instant the grain goes from the condition of rest relative to the sieve to that of sliding over it, $\alpha = \alpha_0$ and $\dot{\alpha} = -w$ if the cylinder revolves in the clockwise direction and the grains move downward. The final expression for the absolute velocity of grain quadrants I and II is given by;

$$\dot{\alpha}^2 = \frac{2g\cos\in}{r\cos\phi}\cos(\alpha - \phi - \in) + \left[w^2 - \frac{2g\cos\in}{r\cos\phi}\cos(\alpha - \phi - \in)\right]e^{-2\alpha\tan\phi} \quad .... (10)$$

Fig. 2 shows the various methods of increasing the speed of rotation of cylindrical sieves. According to the first mode of operation, the grain in lower most layer are in contact with the sieve surface which carries them upward to the limiting angle. Then in second quadrant they begin to slide downward. The speed of rotation of cylinder is;

$$n < \frac{30}{\pi}\sqrt{\frac{g}{r\sin\phi}} \quad .... (11)$$

Performance Evaluation

The overall effectiveness of screen was calculated by;

$E = [(m_f - m_u)(m_o - m_f)\, m_o\, (l - m_u)] / [(m_o - m_u)^2 (l - m_f)\, m_f]$ ....(12)

Material of Construction and Testing

A pyramid shape hopper with 400 × 440 mm top was fabricated. The machine consisted of a feeding device, screen cylinder, power drive and power transmission. A sliding type feed regulating valve was fitted at the lower end of the hopper. Two galvanized-iron wire mesh screen with a mesh opening of 0.495 and 0.392mm respectively, were rolled to make inner and outer screen. A worm type foot mounted speed reducing gear box with 1:30 speed reducing was fitted with V-pulley for further power transmission. Varity MC-43 of cumin seeds were used as a test sample. The machine efficiency was evaluated at 7.5 % moisture content (db), feed rates (30, 50, 70 kg/hr), screen cylinder speed (11, 20, 28 rpm) and screen slope (5, 7, 9 %). Developed cleaner-cum-grader for cumin seed and Power transmission arrangements for machine is shown in **Fig. 3** and **Fig. 4**.

Performance Evaluation

The performance studies of the machine developed for cumin seed in terms of its cleaning efficiency were carried out with reference to different operating parameters. The detailed performance data is presented in **Table 1**. The data indicate that as the slope increased, there was reduction in cleaning efficiency at all the feed rates and screen speeds. This is due to the possible reduction in the residence time. As the feed rate of machine increased from 30 to 50 kg/h, the cleaning efficiency reduced slightly, thereafter on further increased in feed rate up to 70 kg/h, there was a sharp reduction in cleaning efficiency.

Fig. 2 Various methods of increasing the speed of rotation of cylindrical sieve

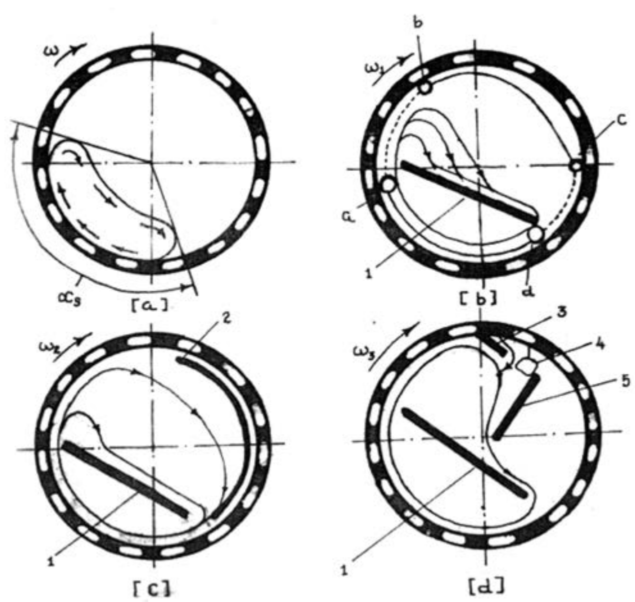
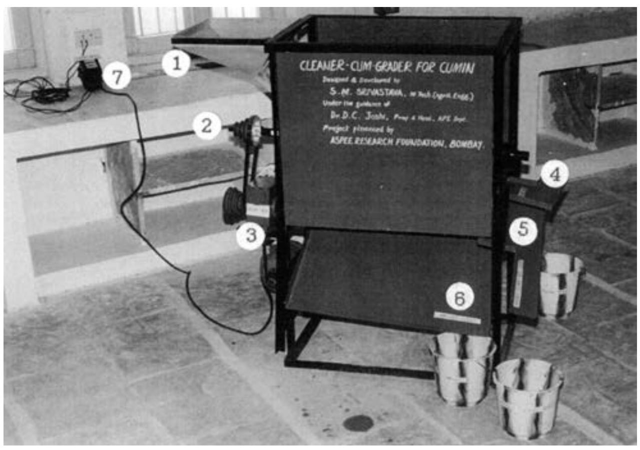


Fig. 3 Developed cleaner-cum-grader for cumin seed

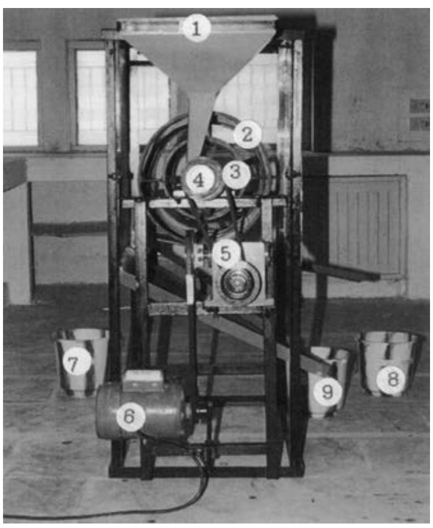


1. Feed hopper, 2. Main shaft, 3. Gear box, 4. Cleaned seed outlet, 5. Partially cleaned seed outlet, 6. Impurities outlet, 7. Energy meter

Table 1 Performance Data of the Cleaner-Cum-Grader at Different Operating Conditions

Screen Speed (rpm)	Feed Rate (kg/h)	Screen Slope (%)	Quantity (g) of seed/ Impurities at								
			Feed Inlet		Clean seed outlet		Partially clean seed outlet		Impurity outlet		Cleaning efficiency (%)
			Clean seed	Impuri-ties	Clean seed	Impuri-ties	Clean seed	Impuri-ties	Clean seed	Impuri-ties	
11	30	5	750	250	726.7	38.7	20.7	132.5	2.4	78.5	82.2
11	30	7	750	250	726.8	38.8	20.5	133.9	2.3	77.9	82.7
11	30	9	750	250	756.0	61.2	12.9	108.5	1.1	80.4	76.0
11	50	5	750	250	731.1	39.3	16.9	132.9	1.9	78.0	82.3
11	50	7	750	250	746.6	50.8	2.9	124.1	0.6	75.1	79.3
11	50	9	750	250	736.8	61.4	11.7	107.7	0.5	80.9	73.9
11	70	5	750	250	745.1	109.3	4.1	75.8	0.9	65.0	55.9
11	70	7	750	250	745.0	109.9	3.8	76.1	1.2	64.1	55.3
11	70	9	750	250	748.1	122.5	1.4	95.4	0.6	32.2	50.5
20	30	5	750	250	726.4	62.3	21.9	130.6	1.7	59.7	72.4
20	30	7	750	250	731.6	58.8	17.7	117.7	0.7	73.7	74.4
20	30	9	750	250	746.3	64.1	3.5	125.7	0.5	60.2	73.5
20	50	5	750	250	743.0	61.8	5.3	126.4	1.7	60.5	74.7
20	50	7	750	250	745.0	59.9	3.8	121.4	0.7	68.9	75.4
20	50	9	750	250	737.7	100.4	11.4	98.4	1.0	55.1	58.8
20	70	5	750	250	745.1	90.3	3.4	99.1	1.4	60.5	63.5
20	70	7	750	250	744.1	80.1	4.4	126.1	1.5	43.8	67.5
20	70	9	750	250	744.1	126.9	2.9	95.2	0.4	27.9	47.6
28	30	5	750	250	729.3	75.4	18.6	120.0	2.1	54.6	68.5
28	30	7	750	250	727.0	70.2	20.9	129.5	1.8	50.2	69.4
28	30	9	750	250	748.2	85	1.1	130.2	0.5	35.0	60.7
28	50	5	750	250	728.5	84.6	20.1	105.1	1.4	60.3	64.0
28	50	7	750	250	729.7	84.9	19.2	104.2	1.1	61.1	63.4
28	50	9	750	250	745.0	102.6	2.3	107.6	0.7	39.8	58.5
28	70	5	750	250	740.3	86	6.4	105.9	3.2	58.2	64.7
28	70	7	750	250	748.3	121.7	1	95.6	0.7	32.8	51.0
28	70	9	750	250	746.1	140.3	2.7	78.1	1.1	31.7	43.5

Fig 4 Power transmission arrangements for machine



1. Feed hopper, 2. Outer screen, 3. Inner screen, 4. Main shaft, 5. Gear box, 6. Motor, 7. Cleaned seed outlet, 8. Partially cleaned seed outlet, 9. Impurities outlet

Clustering of seeds inside the screen cylinder at higher feed rate might reduce the contact area and time between the seed and screen. As the rotational speed of the screen cylinder increases, there are chances that the total retention time for the seeds inside the cylinder screen at a particular combination of scren slope and feed rate might reduce.

Conclusions

A mechanical rotary double screen cleaner-cum-grader was successfully developed for cumin seed. The performance of the machine (cleaning efficiency) was influenced by all three machine operating parameters. Cleaning efficiency of the machine was reduced when the screen slope, screen speed and feed rate were increased. The cleaning efficiency of the machine ranged above 80 % when the machine was operated at 11 rpm screen speed, 5-7 % screen slope and 30-50 kg/h feed rate.

REFERENCES

Birewar, B. R. and S. C. Kanjilal. 1982. Hand operated batch type grain cleaner. Journal of Agricultural Engineering Today, 6(6): 3-5.

Bisht, B. S. and L. K. Sinha. 1985. Performance evaluation of an air screen seed cleaner. Proceedings of silver jubilee convention of

ISAE, 3: 11-61.
Kachru, R. P. and K. M. Sahay. 1988. Separation of oil seeds by pedal-cum-power operated air screen cleaner. Journal of Oil Seed Research, 5: 132-139.
Kachru, R. P. and K. M. Sahay. 1990. Development and testing of pedal-cum-power operated air screen cleaner. Agricultural Mechanization in Asia, Africa and latin America, 21(4): 29-32.
Kathiravan, M., A. S. Ponnuswamy, and C. Vanitha. 2008. Effect of sieve screen size on seed quality of cotton seeds of mcu 12 and surabi in a lab model two screen cleaner cum grader. Agric Sci. Digest, 28(2): 136-138.
Saurabh, P. 1990. Design and development of cleaner-cum-grader for spices. Annual report of Post Harvest Technology, Bhopal: 21-26.
Singh, N. K., P. J. K. Singh, and B. R. Shakya. 1980. Flow of granular food through hopper opening. Journal of Agricultural Engineering, 17(1): 45-48.
Vishwanathan, R., V. V. Sreenarayanan, and K. R. Swaminathan. 1994. Development of hand operated rotary sieve cleaner-cum-grader for sesamum seed. Agricultural Mechanization in Asia, Africa and latin America, 25(2): 35-36.

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NEWS

TICAD V: The Fifth Tokyo International Conference on African Development —CARD Side Event

Coalition for African Rice Development CARD
"An Innovative Attempt toward Food Security and Agricultural Development in Africa"

The seminar on the theme of “Coalition for African Rice Development (CARD)” organized by The Japan International Cooperation Agency (JICA) was taken place as one of the TICAD V official events at Intercontinental Yokohama Grand Hotel on June 3rd and participated by over 150 related parties from around the world.

TICAD stands for "Tokyo International Conference on African Development" and is an international conference discussing importance of African development led by Japan in collaboration with the United Nations, the World Bank and other concerned organizations every five years since 1993. Participants of the conference were 51 countries from Japan and Africa including government leaders and officials of African nations. Prime Minister Shinzo Abe addressed the supportive measures at the opening ceremony on the 1st that “we will implement our “Strategic Master Plan” in ten countries including Kenya and Mozambique and Japan will support African growth through public and private means of 3.2 trillion yen, including ODA of around 1.4 trillion yen over the next five years.” This takes aim at expansion of investment from Japanese corporates and support for economic growth in Africa.

In this seminar, the theme of “The Status of Rice Development in Africa as well as Visions for the Future of Rice Development in Africa” was discussed. In the wake of TICAD IV that was held in 2008, the CARD initiative with the goal to double rice production in sub-Saharan Africa in 10 years (rice-based from 14 to 28 million tons) was started. Focus points have been addressed about the expected role of government and private sector for the promotion of private investment essential to the development of the African agriculture sector further in the future.

Mr. Kishida, President of Shin-Norinsha Co., Ltd. has delivered a speech on the small and medium-sized business and the importance of agricultural mechanization.

Combination Tillage Implement for High Horse Power 2WD Tractors

by
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Abstract

Combination tillage implement comprising cultivator (9 × 0.35 m) and a single-acting disk harrow (8 × 0.6 m) in sequence (C-DH) with a total cutting width of 2.1m was designed and developed for 31 kW power range of tractor. While evaluating the performance of this implement in sandy clay loam soil with a 31 kW 2WD, the draft was found to be within 7.4 to 11.1 kN with an associated slip of 10.5 to 22.4 %. The mean weight diameter (MWD) of soil aggregates, field efficiency and fuel consumption of C-DH were found to be 18.8 mm, 74.2 % and 4.3 l/h, respectively. Taking all these parameters into account, the overall performance of tillage implement was expressed in terms of tillage performance index (TPI). It was found to be higher for combination tillage implement as compared to that of individual tillage implements indicating better efficiency of the tractor-implement combinations.

Introduction

In conventional tillage practices, most of the Indian farmers utilize the available tillage implements with any ranges of tractor power, consequently there is improper matching of tractor and implement combinations resulting in under-loading of tractor engine and hence, poor efficiency (Alam, 2000). The conventional tillage practices are becoming increasingly expensive in terms of time, fuel and equipment costs and are also causing more soil damage and compaction due to higher number of passes required for the conventional implements during seedbed preparation leading to reduction in crop yield (Oni and Adeoti, 1986). Further, the time required by the conventional tillage practices has either limited the area of crop sown or has produced a high machinery and labor requirements for short-working periods, which is uneconomical. These difficulties can be overcome by either increasing speed of operation and width of cut of tillage implements or reducing the number of passes required for tillage operations to prepare the seedbed without sacrificing the quality of work. As the land sizes in India are small, the scope for increasing the speed or width of existing implements is less feasible. Hence, reducing the number of passes by combining two or more field operations with the use of combination tillage implements may provide better solution.

With this view in mind, an attempt was made to develop a combination tillage implement for 2WD tractor and its performance was evaluated at research farm of Agricultural & Food Engineering Department, Indian Institute of Technology, Kharagpur.

Material and Methods

Design and Development of Prototype Combination Tillage Implements

One passive-passive combination

Fig. 1 Developed combination tillage implement

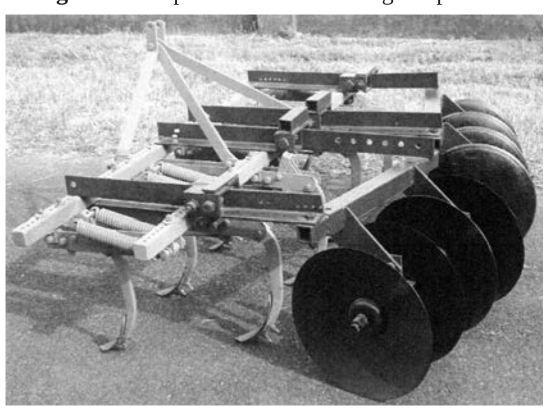


Table 1 Detail specifications of the developed combination tillage implements

Implement	Width of passive sets, m		Overall dimension, m	Weight, kN
	Front	Rear		
C-DH	2.1	1.9	2.1 × 1.4 × 1.1	3.4

Table 2 Soil condition at which different implements were tested

Implement	Cone index, kPa	Bulk density, g/cm^3	Moisture content, % d.b.
Cultivator	856 ± 68	1.4 ± 0.15	9.4 ± 0.7
Offset disk harrow	856 ± 68	1.4 ± 0.15	9.4 ± 0.7
C-DH	856 ± 68	1.4 ± 0.15	9.4 ± 0.7

tillage implement i.e. a cultivator and a single-acting disk harrow in sequence (C-DH) was designed and developed as shown in **Fig. 1**. The front passive set was selected from the tillage implements commonly available in the market for carrying out tillage operations. Only the rear passive set i.e. single-acting disk harrow with supporting frames were designed. The rear passive set was attached to the front passive set by means of bush bearing to act as an independent unit in terms of depth of penetration, assuming that the weight of the rear passive set was sufficient to achieve the optimum depth of penetration. The detail dimensions of the developed combination tillage implement are as given in **Table 1**.

Experimental Procedure for Field Tests

Field testing of combination as well as individual (cultivator and disk harrow) tillage implements was carried in plots of size 50 × 25 m each with three replications using a 31 kW, 2WD tractor. Before starting the experiments, the data on bulk density, moisture content and cone index of soil were collected. The soil condition at which implements were tested is presented in **Table 2**. The performance of tractor-implement combination was evaluated on the basis of tractive and tillage performance parameters. The tractive performance parameters included measurement of draft and slip values whereas the tillage performance parameters included measurement of volume of soil handled per unit time (V_S), mean weight diameter of soil aggregates (MWD), actual field capacity, field efficiency and fuel consumption. Measurement of tillage and tractive performance parameters were carried out following the guidelines of BIS standards (BIS: 6288-1971 and 7640-1975) and utilizing the equations given in the following section.

Draft and Depth of Operation

The draft requirement of tillage implements and its depth of operation in the field were measured with an instrumented three-point linkage of tractor. For measuring draft values, implements were pulled at different speed and depth for a strip of 25 m length and simultaneously data on pulling force and the angle made by the links were recorded through multi-channel data acquisition system.

Slip

The measurement of wheel slip was based on the fixed number of rear wheel revolution. The distance covered in ten wheel revolutions was recorded with and without load and the values were used to calculate slip using the following expression.

$$S = (d_t - d_a) / d_t \times 100 \quad (1)$$

Where, S is slip (%), dt is distance covered in 10 revolutions of drive wheel at no load in field (m) and d_a is distance covered in 10 revolutions of drive wheel with load in field (m).

Volume of Soil Handled

The volume of soil handled per unit time could be expressed as:

$$V_s = AFC \times T_d \times 10000 \quad (2)$$

Where V_s is volume of soil tilled per unit time (m^3/h), AFC is actual field capacity (ha/h) and T_d is depth of operation (m).

Mean Weight Diameter of Soil Aggregate

The mean weight diameter (MWD) of the soil aggregate could be computed as:

$$MWD = \sum_{s=1}^{s=n} W_s M_s / \sum_{s=1}^{s=n} W_s \quad (3)$$

Where MWD is mean weight diameter of soil aggregates (mm), W_s is weight of soil sample retained over sth sieve (g) and M_s is class of mean size for sth sieve (mm).

Fuel Consumption Measurement System

The fuel consumption of tractor during tillage operations was measured with the help of a fuel measuring system comprising an auxiliary fuel tank, valve and pipe connections. The smaller capacity auxiliary fuel tank was attached to the tractor and was interconnected to the original fuel tank of the tractor fuel injection system by a three-way valve with suitable pipe connections. The three-way valve allowed the operator to feed fuel from original tank to run the tractor for other applications and from auxiliary tank during field testing of the implements.

Fuel Energy Input to the Tractor

The fuel (diesel) energy input (F_e) to the tractor to carryout a tillage operation could be expressed as:

$$F_e = FC \times CV \quad (4)$$

Where F_e is fuel energy input (MJ/ha), FC is fuel consumption (l/ha) and CV is calorific value of diesel (MJ/l).

Overall Performance

The overall performance of the tractor implement combination was expressed in terms of tillage performance index (TPI), which is considered to be directly proportional to V_s and S_i and inversely proportional to MWD and fuel energy (F_e). Mathematically, it could be expressed as:

$TPI \alpha \times [V_s / (MWD \times F_e)]$ ....(6)

$TPI = K \times [V_s / (MWD \times F_e)]$ ..(7)

Where K is proportionality constant. While comparing the tillage performance of different tillage implements in same soil condition K could be absorbed in the equation.

For comparative tillage performance, tests were carried out in a 50 × 25 m plot for each tillage practice and were replicated thrice. Before starting a tillage operation, the level of fuel in the auxiliary tank was noted down. Then, the tillage implements were operated in the plots. During tillage operation, the time taken to cover a distance of 25 m was noted for 10 times to measure the average speed of operation. The depth and width of tillage operation were measured along the furrow made by the tillage implements. After completion of the tillage operation, the time of completion of tillage operation and fuel level in the auxiliary tank were noted down. At the end of each tillage practice, the soil samples were collected randomly from ten places of the tilled plot to determine soil pulverization. The soil condition before and after operation of tillage implements are shown in **Fig. 2**.

Results and Discussion

Tractive Performance Parameters

The observed tractive performance parameters (draft and slip) data from the field experiments of prototype tillage implements with 2WD tractor at different depth, speed and soil conditions are graphically presented in **Fig. 3** for both individual and combination tillage implements.

Draft

The results obtained are the average of the three replications. The measured draft forces for cultivator, offset disk harrow and C-DH for 100 and 150 mm depths of operation are shown in **Fig. 3**. From this figure, it can be seen that the draft values for cultivator, offset disk harrow and C-DH implements are found to be within 6.8 to 10.3 kN, 4.7 to 7.4 kN and 7.4 to 11.1 kN, respectively for the test range of soil conditions, depths and speeds of operation.

The draft values of all tillage implements tested show a polynomial increase with increase in depth and speed. The draft of C-DH was found to be the highest among the tillage implements tested. This could be due to higher volume of soil handled per unit width as compared to other tillage implements and also its design and manner of soil handling. The draft values of combination tillage implement as compared to its individual tillage implements were higher by 1.1 to 9.3 %. This lesser increase in draft values was due to

Fig. 2 Soil condition before and after operation of individual and combined tillage implements

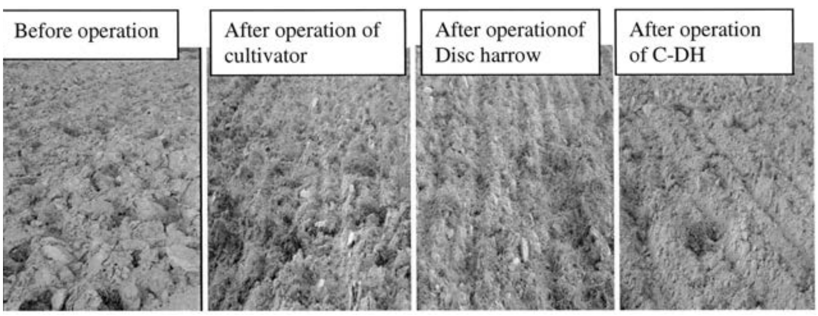
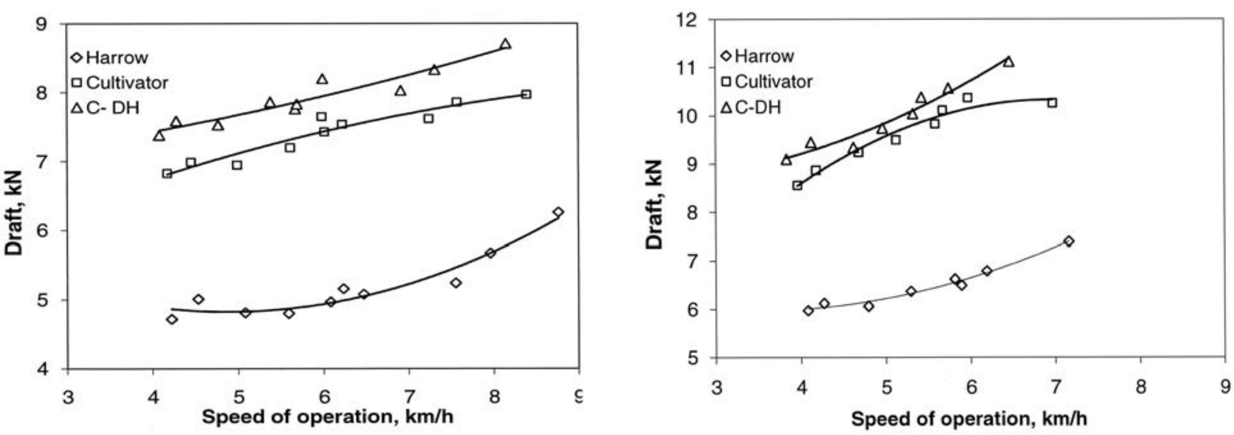


Fig. 3 Variation of draft of cultivator, offset disk harrow and C-DH tillage implement with speed of operation



(a) 100 mm depth of operation

(b) 150 mm depth of operation

Table 3 Tillage performance of different implements

Tillage implement	Mean weight diameter (MWD), mm	Volume of soil handled per unit time (Vs), m^3/h	Actual field capacity (AFC), ha/h	Field efficiency (FE), %	Fuel consumed per unit time (Fu), l/h	TPI[a]
Cultivator	25.7	945.0	0.63	79.7	3.9	0.22
Disk harrow	17.0	637.5	0.51	80.2	3.6	0.24
C-DH	18.8	885.0	0.59	74.2	4.3	0.26

[a] calculated on the basis of caloric value of diesel equal to 42 MJ/l

the movement of the rear passive set in a soil already disturbed by the front set.

Slip

The measured slip obtained from the field experiments of tillage implements at different depths, speeds and soil conditions are also presented in **Fig. 4**. It can be noticed that the slip of driving wheels of the tractor with cultivator, offset disk harrow and C-DH implements was found to be within 8.6 to 16.9 %, 7.5 to 13.9 % and 10.5 to 22.4 %, respectively. Further for all implements, it increased with increase in both depth and speed. This behavior could be due to higher draft requirement of an implement with increase in depth, speed and soil strength causing thrust requirement at drive wheels to increase and thus resulting in more slip.

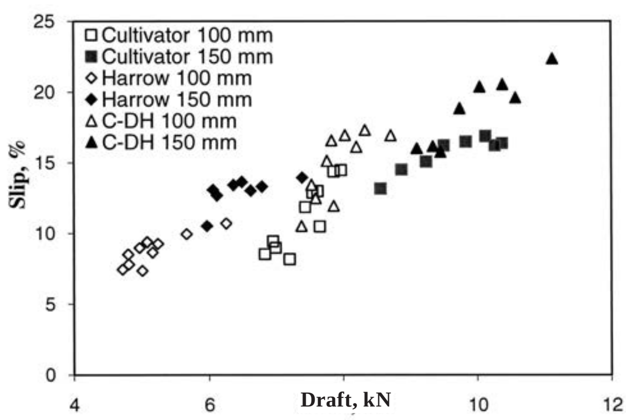
Tillage Performance

The tillage performance data obtained from the field experiments of all tillage implements tested are presented in **Table 3**.

Mean Weight Diameter of Soilaggregates

The MWD of soil aggregates was determined using the data obtained from the sieve analysis of soil sample collected after single pass of each tillage implement. From Table 3, it can be seen that the MWD of soil aggregates varied from 17.0 to 25.7 mm for the tillage implements used. The disk harrow produced the lowest MWD of soil aggregates (17.0 mm), while the cultivator produced the highest MWD (18.8 mm). This could be due to both cutting and pulverizing actions by disk harrow as compared to only cutting action by cultivator. It can also be seen that the MWD of soil aggregates produced by C-DH combination tillage implement was lower than the conventional cultivator. This could be due to proper shattering of the soil mass by the rear passive set of combination tillage implement in addition to the cutting made by the front passive set during tillage operation.

Fig. 4 Variation of slip of tillage implements with increase in draft



Actual Field Capacity

The actual field capacity of various tillage implements tested in the field varied from 0.51 to 0.63 ha/h and is presented in **Table 3**. A maximum of 0.63 ha/h and a minimum of 0.51 ha/h were observed for cultivator and disk harrow, respectively. This could be due to the difference in speed at which they were tested. The actual field capacity of cultivator was found to be 6.35 % higher than that of combination tillage implement. This was due to more time required during turning for combination tillage implement as well as lesser speed of operation due to higher slip.

Volume of Soil Handled per Unit Time

The volume of soil handled per unit time during tillage operation was calculated knowing the implement width, speed and depth of operation for each tillage implement tested and was found to be varying from 637.5 to 945.0 m^3/h as reported in **Table 3**. As compared to cultivator, the volume of soil handled per unit time for C-DH implement was 6.35 % lesser due to higher slip incurred and losses in time during turning.

Field Efficiency

It can be seen from **Table 3** that the field efficiency of different tillage implements tested varied from 74.2 to 80.2 %. The highest and lowest field efficiencies were found for disk harrow and C-DH combination tillage implement, respectively. This could be due to more time loss during turning of C-DH implement as compared to disk harrow.

Fuel Consumption

The fuel consumption of 31 kW tractor for all the tillage implements tested varied from 3.6 to 4.3 l/h and is presented in **Table 3**. It was found that C-DH tillage implement consumed the highest amount of fuel (4.3 l/h), while the lowest (3.6 l/h) was observed for disc harrow. This could be due to more volume of soil handled by C-DH as compared to other tillage implements. However, on the basis of area covered, the fuel consumption was found to be lowest (6.2 l/h) for cultivator due to its higher actual field capacity.

Tillage Performance Index

The overall performance of different tillage implements tested during the study was expressed in terms of tillage performance index (TPI) and is presented in **Table 3**. From this figure, it can be seen that the TPI varied from 0.22 to 0.26 for the tillage implements tested. The highest TPI was found for C-DH tillage implement, while the lowest was found for cultivator. This could be due to more volume of soil handled and higher pulverization by C-DH as compared to disk harrow and cultivator.

Conclusions

1. The developed combination tillage implement could be operated with 31 kW, 2WD tractor in sandy clay loam soil at an average m.c. of 10 %, normal depth and speed within the slip range of 15 %.
2. The overall performance of different tillage implements could be expressed in terms of tillage performance index (TPI) taking into account the MWD of soil aggregates, soil inversion, volume of soil handled per unit time and fuel consumption. The TPI of combination tillage implements was found to be higher than the TPI of respective individual tillage implements.

Acknowledgment

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REFERENCES

Alam, A. 2000. Farm mechanization: Rising energy intensity. The Hindu Survey of Indian Agriculture, 181-191.

BIS: 6288. 1971. Test code for mouldboard ploughs. Bureau of Indian Standards. New Delhi,India.

BIS: 7640. 1975. Test code for disc harrows. Bureau of Indian Standards. New Delhi, India.

Oni, K. C. and J. S. Adeoti. 1986. Tillage effects on differently compacted soil and on cotton yield in Nigeria. Soil and Tillage Research 8: 89-100.

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Performance Evaluation of Experimental Self-Propelled Double Row Sugarcane Harvester

by

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Abstract

India produces more than 340 millions tonnes of cane at an average rate of 70 tonnes per ha. It is grown by small, medium and big farmers, but 83 % of sugarcane growers fall in small holder category. Sugarcane harvesting is the single most expensive and labour intensive operation in sugarcane farming. Whole Stalk harvesting or Cut-chop harvesting are expensive systems and as such beyond the capacity of average farmer of developing countries. Most of the sugarcane farmers in developing countries use a handheld knife to cut the sugarcane stalks at the base level and green top by impact force. In some developing countries, including India, farmers are beginning to face labour shortages, because of recurring labour scarcity during harvest season. It is desirable to transport the harvested cane to the factory within 24 h, as the yield declines by 0.4 % per day after cutting. In this study an experimental self-propelled double row sugarcane harvester powered by an 8 hp diesel engine was used. The machine was evaluated for field capacity (ha/h), fuel consumption (l/h) and material capacity (t/h) as dependent parameters and forward speed (2 level), method of collection (viz. guide bar method and rope method) and cutter bar speed (3 level) as the independent parameters. The experiment was conducted for trench planted sugarcane crop. The optimum parameters were found at; forward speeds 1.0-1.4 km/h, guide bar and 1,020 strokes/min of knife bar in trench plant cane.

Introduction

India is the second largest sugar producing country of the world. It occupies an area of about 4.41 mha (Anon., 2008a). India produces more than 340 million tonnes of cane at a national average of 70 tonnes per ha (Anon., 2008b). About 83 % of sugarcane growers are small farm holders (Sharma *et al*., 2006). Sugarcane plantations are concentrated mainly in nine Indian states, viz; Andhra Pradesh, Bihar, Gujarat, Haryana, Maharashtra, Punjab, Tamil Nadu, Uttar Pradesh, and Uttaranchal. The sugarcane harvesting season falls between August and January, but it varies from region to region, as India is a large country with two distinct climatic zones, one tropical and one subtropical, and sugarcane is grown differently in each of these zones.

Sugarcane harvesting is the single most expensive operation in sugarcane farming. Sugarcane harvesting is done by skilled workers who are well experienced in harvesting the cane in order to maximize sugar yield, and without damaging the cane stumps at the ground level as these are essential for the ratoon sugarcane crop. Manual harvesting involves cutting the stalks and removing the green tops, detrashing, bundling and loading of cane in transport vehicle.

In some developing countries, sugarcane farmers face acute labour shortage, during harvest season. Farmer often uses strategy of early harvest and stock piling of the harvested cane before delivery date to the sugar processing mills. In this process, some of the cane deteriorates in quality. Hence, it is desirable to transport the harvested sugarcane to the factory within 24 h, since the yield decreases by 0.4 % per day after cutting (Bhaholyodin *et al*., 1988).

Manual harvesting is also quite commonly used by Indian sugarcane growers. There is acute shortage of skilled manual labour, which is leading to considerable problems for Indian sugar mills. Sugarcane harvesting is a tedious task, and not very well paid. Hence, it is difficult for many plantations to find workers

Table 1 Specifications of double row Self Propelled sugarcane harvester

Particulars	Dimension/type
Name and type of machine	Self propelled, walk behind type
Engine	Diesel engine
Power source and type of cooling	8hp and air-cooled
Number and types of blades	12, serrated blades
Width of cut, mm	1000
Number of gear	3
Power transmission	From engine through pitman shaft, which in turn drive the cutter bar
Dimensions	Overall length: 1000 mm Overall width: 800 mm Overall height: 1000 mm
Traction device	Double wheel, 4-10 inch.
Starting	By using rope
Controls	Brake, clutch, Forward and Backward direction

Table 2 Machine parameters

Independent Parameters	Levels	Values	Dependent Parameters
Forward speed	2	a) 1.00-1.40 km/h (F1) b) 1.50-1.90 km/h (F2)	Fuel consumption, l/h
Method of collection	2	a) Guide bar method (M1) b) Rope method (M2)	Field capacity, ha/h
Cutter bar speed	3	a) 550Strokes/min (C1) b) 800 Strokes/min (C2) c) 1020 Strokes/min (C3)	Material capacity, t/h

who can harvest the cane properly.

Mechanical harvesters are expensive to purchase, and also expensive to run. Mechanical cane harvesters are also large, heavy equipment that cause considerable soil compaction. Sugarcane needs medium to heavier soil in order to grow well. Cane harvesters also damage the roots of sugarcane far more severely and far more often than manual harvesters. Sugarcane roots are important, as they will sprout and grow again, sometimes up to twelve times, though this is an exceptional number and usually only associated with special strains of Brazilian sugarcane. The typical number of re-growth is between three and six. Destroying roots during the first harvest, therefore, represents a significant yield loss from a single planting. Sugarcane harvesting continues to evolve over time.

Cane harvesters are in wide use in countries like Australia, Brazil and America. These are broadly of two types, namely, Sugarcane Combines and Wholestalk Harvesters. Functions performed by combine are detopping, base-cutting, chopping, the cane stalk into billets, trash removal, conveying and loading. The whole stalk harvesters detop, base cut and windrow the cane stalks. Loaders subsequently pick up the windrow cane manually or mechanically. These machines are usually operated after burning the cane to reduce the trash content.

Sugarcane combines are usually self-propelled and generally require over 100 kW engine (Briscoc, 1970). Sharma and Singh (1985) designed and developed a rear mounted tractor operated sugarcane harvester. It cuts cane with ground level and windrows the harvested stalk. The capacity of the machine was 0.25 ha/h. Gupta *et al.*, (1996) developed a self-propelled single-axle sugarcane harvester powered by 6 kW (8 hp) gasoline engine. It was primarily developed for farmers of developing countries who cannot afford to purchase expensive sugarcane harvester used in developed countries. In the field test, the average field capacity of the machine was found to be 0.13 ha/h with average field efficiency of 71 %.

Thus, it may be appropriate to introduce a whole stalk harvester in view of its lower cost. However, this harvester may not include detopping because tops are used as an animal feed in many developing countries. Therefore, there is a need to develop a suitable harvester to suit local conditions and mechanize sugarcane harvesting in India.

Materials and Methods

A double row, self propelled, walk behind type sugarcane harvester was developed and evaluated in the Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana during the year 2008-09. The specifications of the equipment are given in **Table 1**. The independent and dependent parameters selected for the study are given in **Table 2**.

Methods of Planting

There are three methods of planting, viz, flat-planting, furrow-planting and trench-planting.

Flat-planting

In this method, shallow furrows are opened with a desi plough, 80 to 100 cm apart; the setts are placed in the furrows end to end and covered with 5 to 7 cm of soil, and the field is leveled with a heavy plank (sohaga).

Furrow-planting

Furrows are drawn by a ridger, about 10 to 15 cm deep, in northern India and about 20 cm deep in Peninsular India. Setts are laid end to end in the furrows and covered with 5 to 7 cm of soil, leaving the upper portion of the furrows unfilled.

After planting and covering the setts, water is let into the furrows. In some parts of Tamil Nadu, particularly in heavy clay soils, water is first let into the furrows to soak its bed thoroughly and the cane setts are then dropped into the furrow and pressed into the mud by feet. In the case of monsoon planting, as a precaution against the stagnant water in the furrows damaging the buds, the setts are placed inclined on the side of the furrow, instead of flat at the bottom of the furrows.

Trench Planting

Trenches, 20 to 25 cm deep with rectangular or trapezoidal in section, are made either by manual labour or by a tractor-drawn ridger; the bottom of the furrow is loosened by digging (**Fig. 3b**). Shallow furrows are made in the bed of the trench and the setts are placed end to end in the furrows and covered,by soil as in the case of flat-planting. Water is then let into the trenches. Trench-making, setts planting applying fertilizer and pesticides and covering the setts in the trenches are done simultaneously by a tractor-drawn planter.

In most parts of northern India and Bihar, and in the Malnad tract of Karnataka, cane is planted on flatland. Furrow-planting is practiced in parts of eastern Uttar Pradesh and in Peninsular India, and trench-planting is done in some coastal areas where the crop grows very tall and the strong winds are liable to bend the cane and damage them. Planting is done dry or wet. In the canes of dry method, irrigation is not applied at planting time or immediately after that, the planted setts germinate in the comparatively dry soil. In wet planting, on the other hand, the field is irrigated just before or after planting or at both times so that setts germinate in wet soil. Whether the furrows are irrigated before or after planting makes little or no difference. Indeed, in most cases the planted field gets additional irrigations to keep it wet throughout the period of germination.

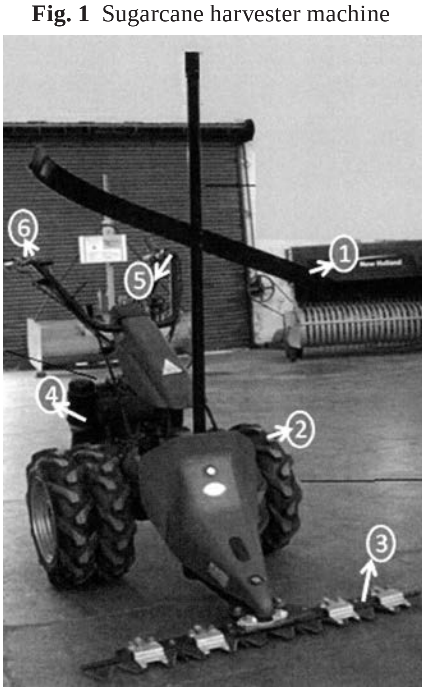
Constructional Description of the Harvester

A double row self-propelled walk behind harvester operated by 8 hp diesel engine was used to cut the sugarcane sticks of variety COJ-87 by using single acting reciprocating knife type cutter bar of 1m size. Power transmission to the cutter bar was provided by a pitman shaft which was connected to the engine through clutch and gear box. The desired cutter bar speed was maintained by means of a engine accelerator placed near the handle. Cutter bar worked on the principle of shearing of the cane stalks and cut sugarcane stalks close to the ground to minimize the losses. As the machine moved along the row, the cut cane stalks were laid in windrow by using the rope and guide bar method. Power to the wheels was provided from the engine through clutch and gear box. These all are on handle for easy and safe operation. The stationary view of the machine is shown in **Fig. 1**.

Method of Collection and Planting

A rope and guide bar method was used for windrowing the cut sugarcane stalks. For using the rope method, the rope was always placed inside the row. Hence some idle time was required for cutting of each cane and five labours were required

Fig. 1 Sugarcane harvester machine



1: Guide bar, 2: Pnematic wheel, 3: Cutter bar, 4: Engine, 5: Break and 6: Accelerator

Fig. 2 Schematic diagram of guide bar

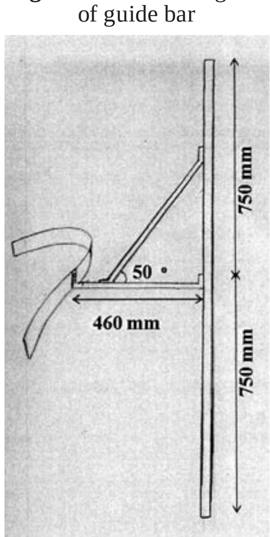


Fig. 3 Trench planting method

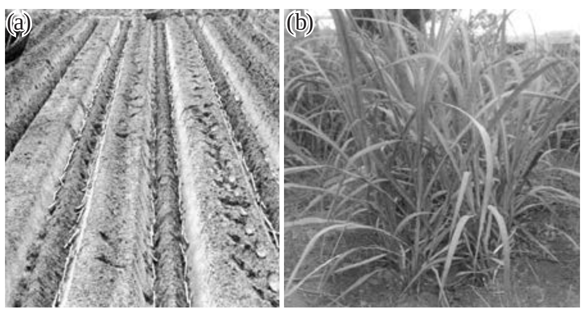


Fig. 4 Sugarcane harvester at the time of harvesting operation

Table 3 Experimental data of fuel consumption of sugarcane harvester in trench planting

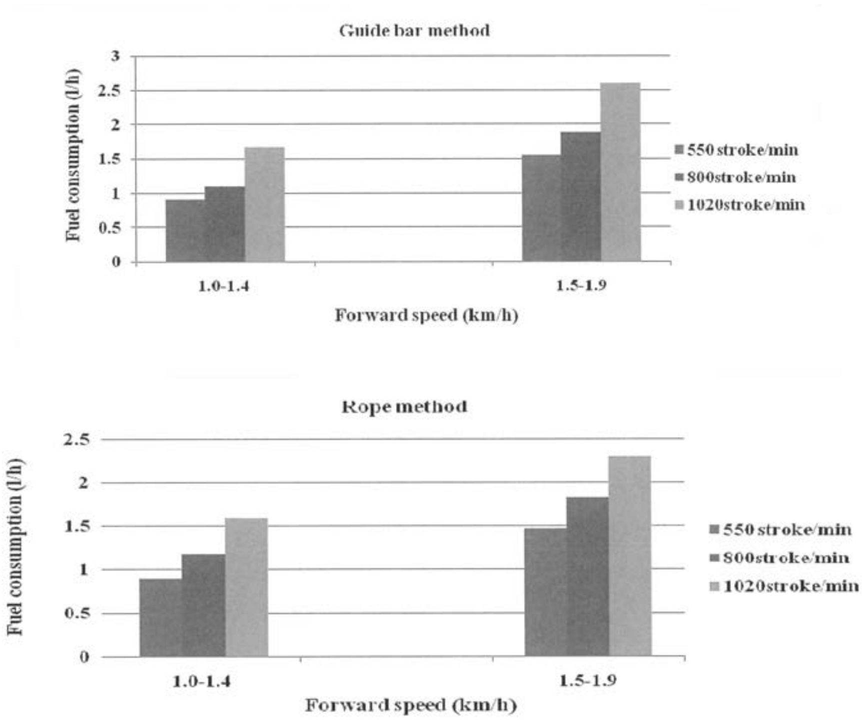
Forward speed, km/h	Method of collection	Cutter bar speed, Strokes/min	Fuel consumption, l/h			
			i	ii	iii	Avg
1.0-1.4 (1st gear)	Guide bar method	550	0.87	0.93	0.95	0.92
		800	1.05	1.13	1.11	1.10
		1020	1.66	1.80	1.54	1.66
	Rope method	550	0.87	0.85	0.93	0.88
		800	1.18	1.11	1.23	1.17
		1020	1.58	1.67	1.50	1.58
1.5-1.9 (2nd gear)	Guide bar method	550	1.44	1.57	1.65	1.55
		800	1.86	1.83	1.96	1.88
		1020	2.72	2.42	2.65	2.59
	Rope method	550	1.38	1.54	1.46	1.46
		800	1.77	1.76	1.92	1.82
		1020	2.17	2.35	2.27	2.29

for the operator. To reduce this labour requirement and time, a guide bar to windrow the cut sugarcane crop was developed which helped in labour and time saving. For the development of the guide bar, MS Flat of size 3 "x ¼" and B class high pressure M.S. pipe of length 1.5 m length was used (**Fig. 2**). The field trials were conducted in a field with trench planted cane, with row to row spacing of 90 cm and 30 cm for alternate rows. A view of planting method is shown in **Fig. 3a**.

Experimental Layout and Evaluation Procedure

A 20 m long sugarcane row was selected for each cutting. Forward speed was selected along with the cutter bar speed and method of collection. Labour requirement was constant for rope and guide bar method, viz. 5 labours for rope method and 3labourers for guide bar method. Considerable time was required for providing the rope in the inter row spacing. The machine was run in the required speed in the chosen gear to cut the cane standing in row and required time to cut the row, fuel and weight of cut sugarcane stalk were recorded. Similar experiments were conducted on different combinations of parameters for cutting the sugarcane for every row in the sugarcane field. During field experiments, an auxiliary five litre fuel tank was fitted on the machine to monitor fuel consumption. The auxiliary tank was installed to a fixed mark on the tank before starting the operation in the field. After harvesting the plot, the machine was stopped and fuel tank was refilled to the fixed level with a 250 ml measuring jar. The quantity of fuel required for refilling was recorded and fuel consumption was calculated.

Fig. 5 Effect of forward speed on fuel consumption in trench planting



Results and Discussion

Effect of Forward Speed on Fuel Consumption

Effect of forward speed on fuel consumption for different methods of collection and cutter bar speed are given in a **Table 3** and trend shown in **Fig. 5**. In general, fuel consumption increased with the increase in forward speed. The maximum fuel consumption of 2.59

Fig. 6 Effect of cutter bar speed on fuel consumption in trench planting

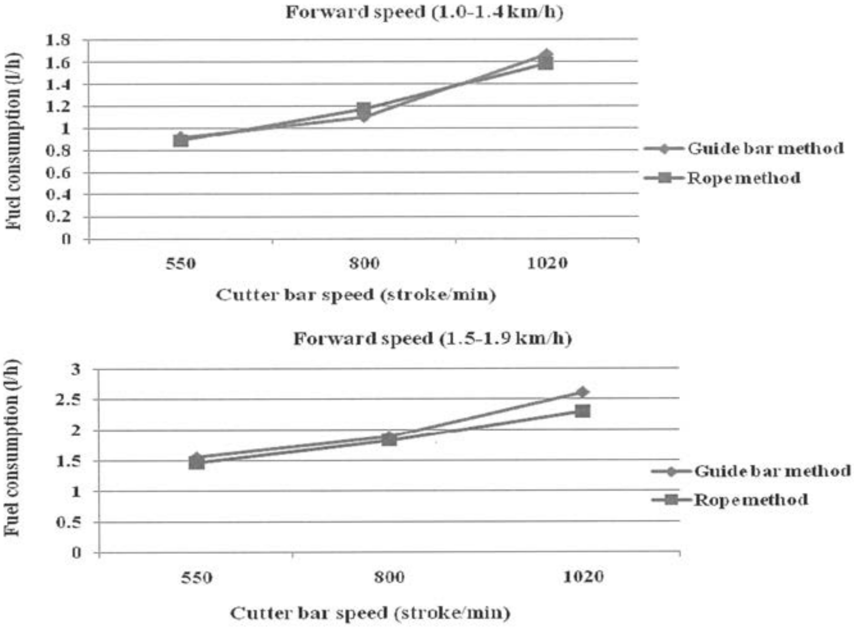
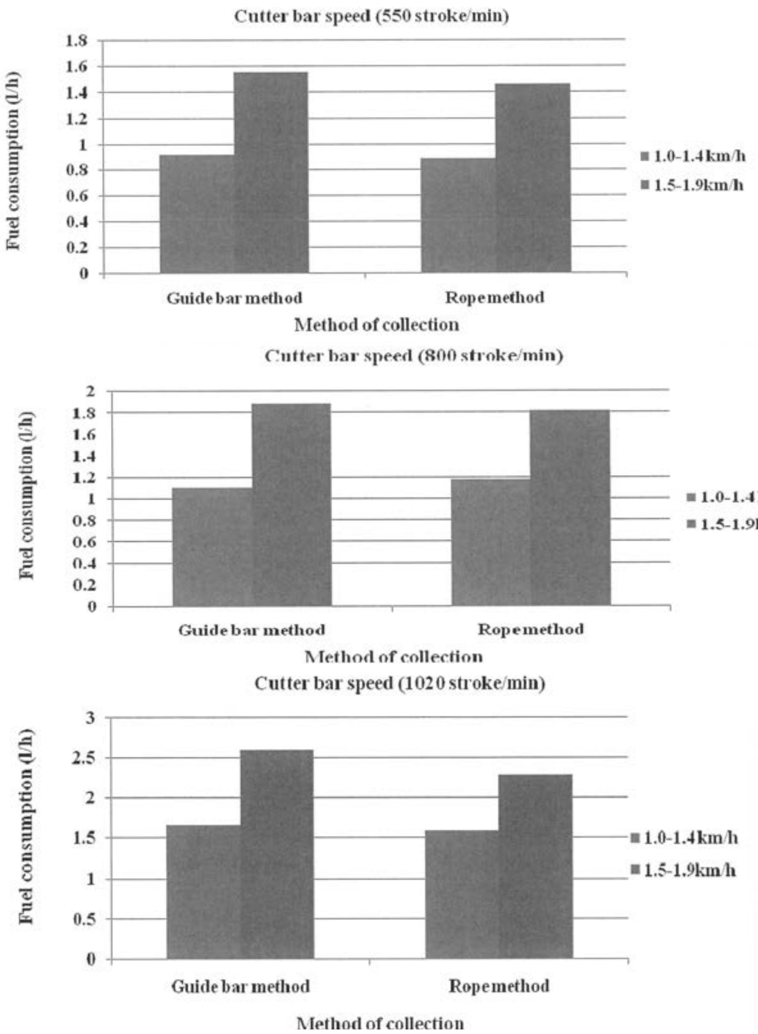


Fig. 7 Effect of method of collection on material capacity in trench planting



l/h was observed at forward speed between 1.50-1.90 km/h and at cutter bar speed of 1020 Strokes/min. The values of fuel consumption of 0.88 l/h and 0.92 l/h, were at observed at forward speed of 1.00-1.40 km/h and cutter bar speed 550 of strokes/min. The fuel consumption in trench planting was more because two rows of cane were cut at a time and the cane density was more.

Effect of Cutter Bar Speed on Fuel Consumption

Effect of cutter bar speed on the fuel consumption for different methods of collection and forward speed is given in **Table 3** and trend shown in **Fig. 6**. In general, fuel consumption increased with increase in cutter bar speed for each method of collection and forward speed of the machine. The values of fuel consumption were 1.69 and 2.59 l/h at cutter bar speed of 1020 strokes/min with guide bar method. The fuel consumption varied between 0.88 and1.55 l/h at cutter bar speed of 550 strokes/min with rope method and at 1.50-1.90 km/h forward speed.

Effect of Method of Collection on Fuel Consumption

Effect of method of collection on the average fuel consumption at different forward speed and cutter bar speed is given in **Table 3** and trend shown in **Fig. 7**. In general, fuel consumption was more in guide bar method. From the data presented in **Table 3**, it was concluded that at cutter bar speed of 550 strokes/min and for guide bar method, when forward speed was 1.00-1.40 km/h, fuel consumption increased from 0.92-1.66 l/h. and at forward speed of 1.50-1.90 km/h, fuel consumption increased from 1.55-2.59 lit/hr. Similarly for rope method, at forward speed of 1.00-1.40 km/h, fuel consumption increased from 0.88-1.58 l/h and at forward speed of 1.50-1.90 km/h, fuel consumption increased from 1.46-2.29 l/h.

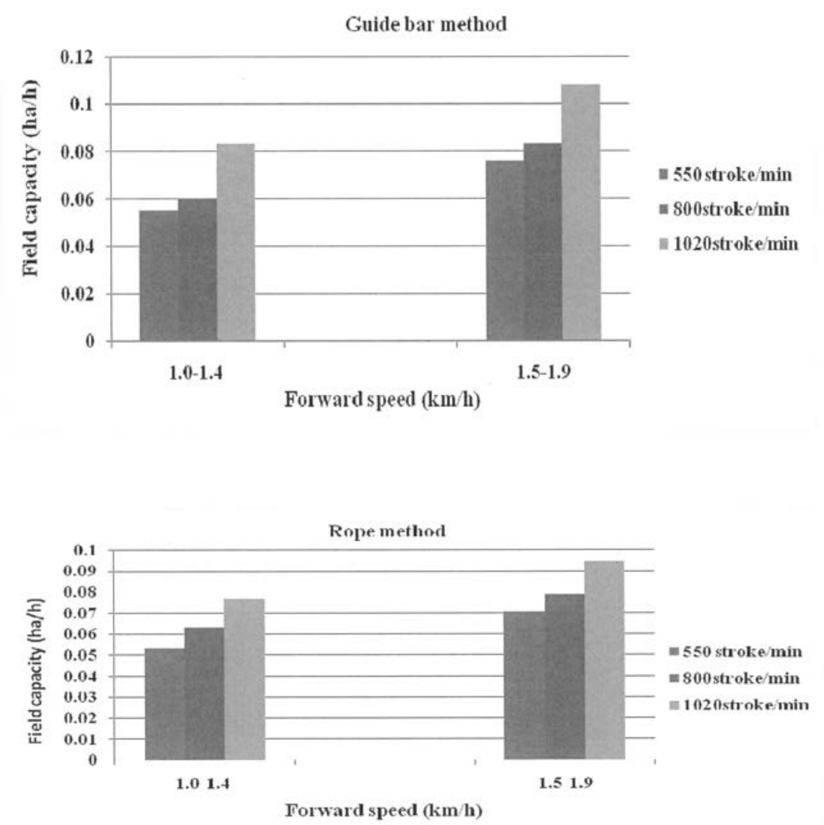
Table 4 Experimental data of Field capacity of sugarcane harvester in trench planting

Forward speed, km/h	Method of collection	Cutter bar speed, Strokes/min	Field capacity, ha/h			
			i	ii	iii	Avg
1.0-1.4 (1st gear)	Guide bar method	550	0.055	0.055	0.054	0.055
		800	0.060	0.059	0.061	0.060
		1,020	0.083	0.086	0.080	0.083
	Rope method	550	0.052	0.053	0.053	0.053
		800	0.064	0.063	0.061	0.063
		1,020	0.076	0.078	0.075	0.076
1.5-1.9 (2nd gear)	Guide bar method	550	0.075	0.079	0.074	0.076
		800	0.083	0.085	0.082	0.083
		1,020	0.112	0.105	0.107	0.108
	Rope method	550	0.069	0.071	0.070	0.070
		800	0.076	0.079	0.080	0.078
		1,020	0.096	0.094	0.092	0.094

Effect of Forward Speed on Field Capacity

Effect of forward speed on field capacity for different methods of collection and cutter bar speed is shown in **Table 4** and trend depicted in **Fig. 8**. In general, the field capacity increased with the increase in forward speed. The values of field capacity were 0.076-0.108 ha/h at forward speed of 1.50-1.90 km/h and at cutter bar speed of 1,020 stroke / min. The values of field capacity was 0.053-0.076 ha/h at forward speed of 1.00-1.40 km/h and cutter bar speed of 550 Strokes/min.

Fig. 8 Effect of forward speed on field capacity in trench planting



Effect of Cutter Bar Speed on Field Capacity

Effect of cutter bar speed on the field capacity for different methods of cane collection and forward speed is depicted in **Table 4** for flat bed planting, and trend shown in **Fig. 9**. In general, field capacity increased with the increase in cutter bar speed for collection and forward speed of the machine. The values of field capacity were 0.076-0.108 ha/h at cutter bar speed of 1,020 strokes/min, for the guide bar method and forward speed of 1.50-1.90 km/h. The values of the field capacity varied from 0.053-0.076 ha/h at cutter bar speed of 550 strokes/min for rope method and at forward speed of 1.50-1.90 km/h.

Effect of Method of Collection on Field Capacity

Effect of method of collection on the field capacity at different forward speeds and cutter bar speed is shown in **Table 4** for flat bed planting, and trend shown in **Fig. 10**. The maximum values of field capacity was 0.083 ha/h and 0.108 ha/h at cutter bar speed of 1,020 strokes/min for guide bar method at forward of speed 1.50-1.90 km/h. The minimum values of the method of collection varied from 0.053 ha/h and 0.070 ha/h were found at cutter bar speed of 550 strokes/min with rope method at 1.00-1.40 km/h.

Fig. 9 Effect of cutter bar speed on field capacity in trench planting

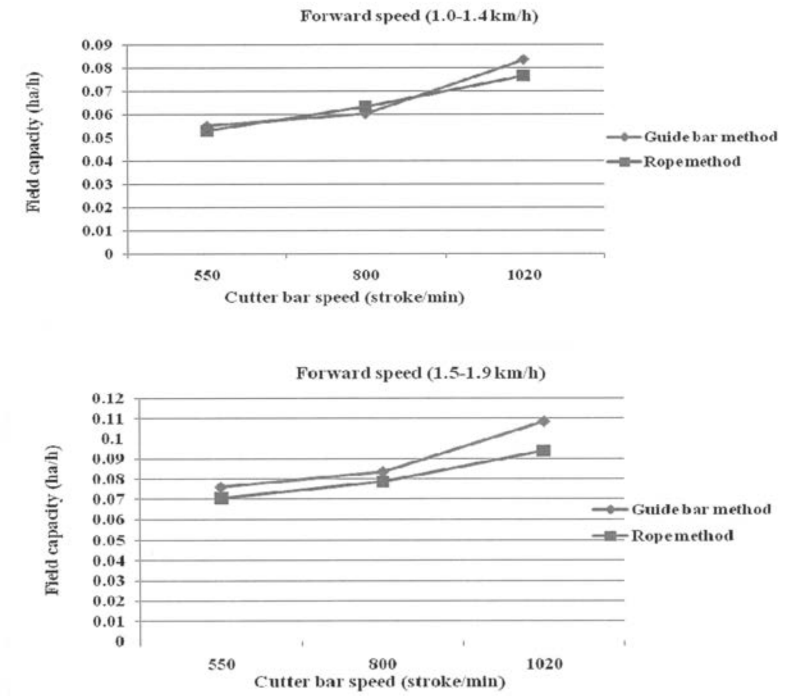
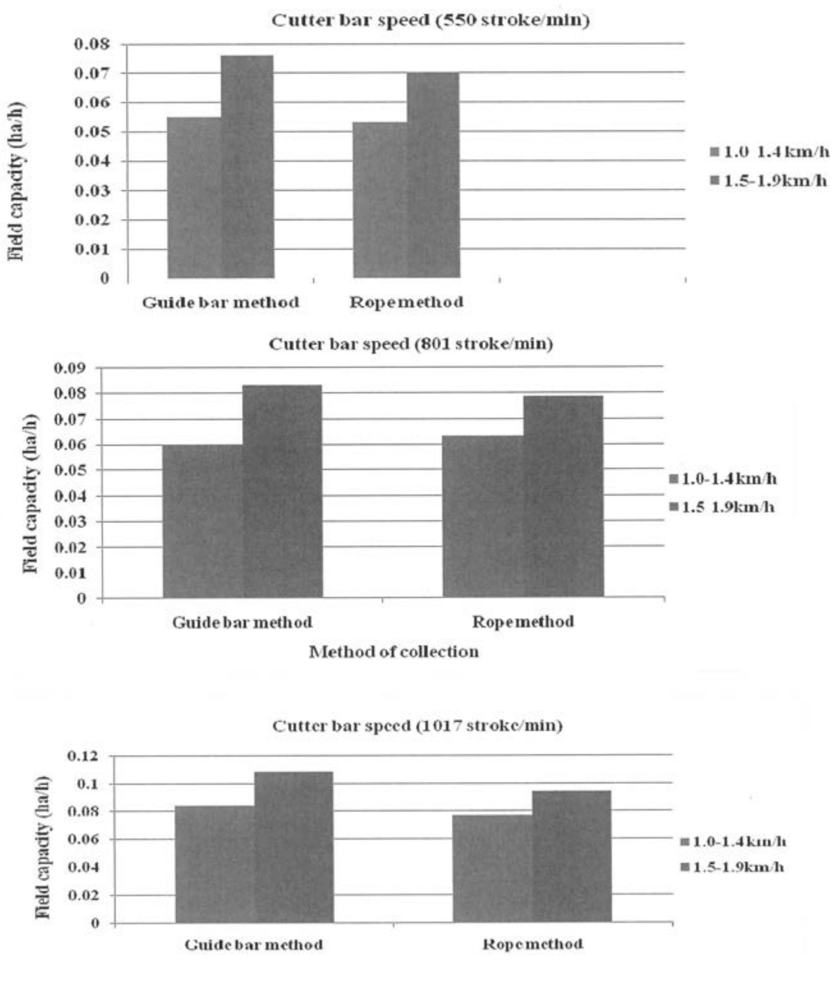


Fig. 10 Effect of method of collection on field capacity in trench planting



Effect of Forward Speed on Material Capacity

Effect of forward speed on material capacity for different method of collection and cutter bar speed is shown in a **Table 5** and trend shown in **Fig 11**. In general, material capacity increased with the increasing forward speed and cutter bar speed. The values of the material capacity varied between 18.93-23.22 t/h at forward speed 1.50-1.90 km/h, at cutter bar speed 1,020 strokes/min. The values of material capacity were 11.22 t/h and 11.40 t/h, at forward speed 1.00-1.40 km/h, cutter bar speed at 550 strokes/min.

Effect of Cutter bar Speed on Material Capacity

Effect of cutter bar speed on the material capacity corresponding to different method of collection and forward speed is indicated in **Table 5** of ridge bed planting and trend shown in **Fig. 12**. In general, material capacity increased with the increase in cutter bar speed irrespective of method of collection and forward speed of the machine.

Effect of Method of Collection on Material Capacity

Effect of method of collection on average material capacity at different forward speeds and cutter bar speed is shown in **Table 5** and trend shown in **Fig. 13**. In general, material capacity was more for the guide bar method. The values of material capacity for guide bar method were 17.34-23.22 t/h and for rope method 15.48-18.93 t/h, at 1.50-1.90 km/h at cutter bar speed of 1,020 strokes/min. The values of material capacity for guide bar method varied between 11.40-14.86 t/h and for rope method between 11.22-14.25 t/h, at 1.00-1.40 km/h and cutter bar speed 550 strokes/min. The optimum operational parameters are shown in **Table 6**.

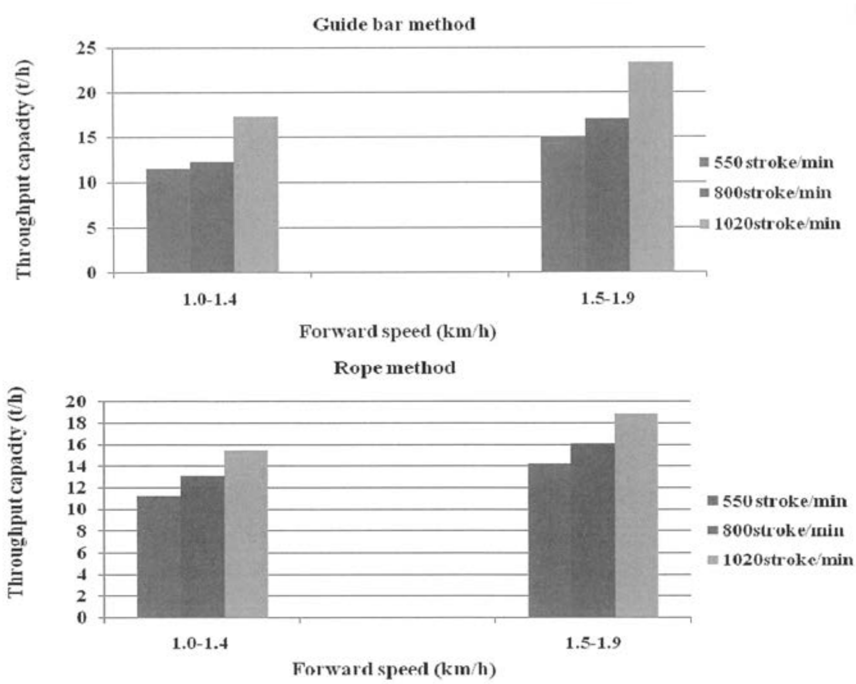
Table 5 Experimental data of material capacity of sugarcane harvester in trench planting

Forward speed, km/h	Method of collection	Cutter bar speed, Strokes/min	Field capacity, ha/h			
			i	ii	iii	Avg
1.0-1.4 (1st gear)	Guide bar method	550	11.09	11.54	11.58	11.40
		800	12.53	11.36	12.59	12.16
		1020	16.39	18.29	17.35	17.34
	Rope method	550	11.07	11.00	11.60	11.22
		800	13.78	13.94	11.83	13.18
		1020	15.67	16.69	14.09	15.48
1.5-1.9 (2nd gear)	Guide bar method	550	15.53	14.77	14.28	14.86
		800	17.39	17.80	15.77	16.99
		1020	25.63	22.60	21.43	23.22
	Rope method	550	13.29	14.45	15.01	14.25
		800	16.47	15.47	16.58	16.17
		1020	19.67	18.51	18.62	18.93

Table 6 Optimum parameters for experimental sugarcane harvester

Trench planting					
Forward speed, km/h	Method of collection	Cutter bar speed, Strokes/min	Fuel consumption, l/h	Field capacity, ha/h	Material capacity, t/h
1.00-1.40	Guide bar	1020	1.66	0.083	17.34
1.50-1.90	Rope method	1020	2.29	0.094	18.93

Fig. 11 Effect of forward speed (Strokes/min) on throughout capacity in trench planting



Conclusions

1. The experimental sugarcane harvester worked satisfactorily for ridge planting method.The fuel consumption was 1.53 l/h, field capacity 0.065 ha/h and throughput capacity was 9.87 t/h, at forward speed 1.00-1.40 km/h for the guide bar method.
2. There was significant effect of forward speed on fuel consumption of the machine and it also increased due to increase in crop density. Field capacity and throughput capacity also increased with increase in forward speed.
3. Guide bar method of collection consumed more fuel than rope method, but the labour requirements (5 man-h/ha for rope method and 3 man-h/ha in guide bar method) were reduced by 66 %. This system comprised simple bar mechanism for guiding of cut stalks to one side to stop being crushed under the tires. The time required to insert the rope inside the crop was more; due to this the labour required in case of rope method was always more than that of guide bar method of handling the harvested cane stalks.
4. The harvesting operation was affected due to cane leaves, uneven row on ridge were major obstacle in the harvesting operation, while the lodged and irregular shape of stalk produced more split stalks.
5. The throughput capacity increased with the increase in the yield of sugarcane.

Fig. 12 Effect of cutter bar speed on throughout capacity in trench planting

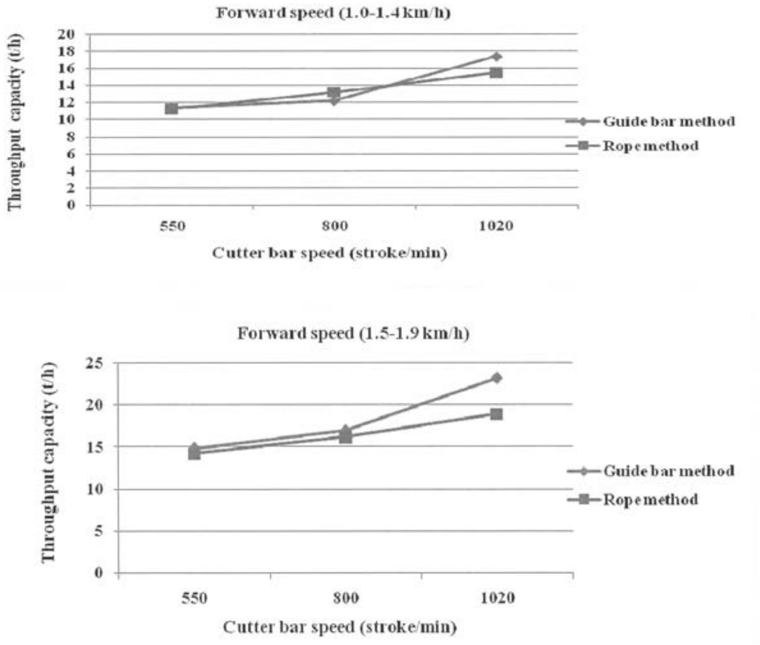
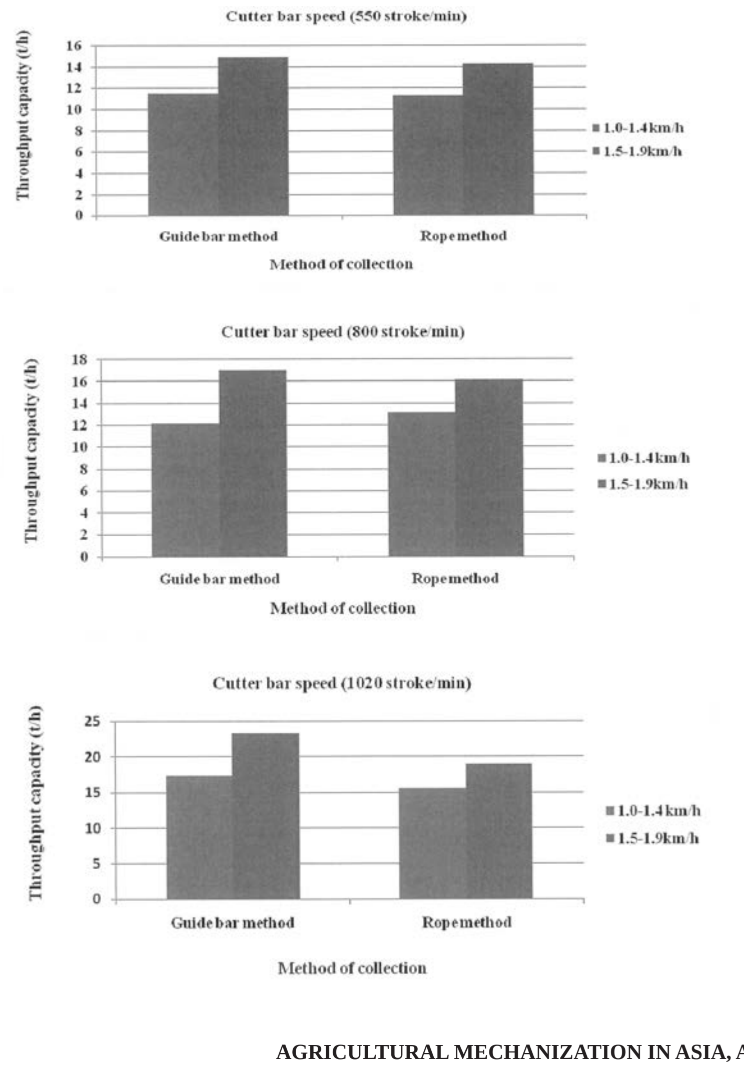


Fig. 13 Effect of method of collection on material capacity in trench planting



6. This harvester could cut the canes stalks, but labour was still required for detrashing operation.
7. The optimum operational parameters were, forward speed of 1.00 -1.40 km/h, guide bar method and cutter bar speed of 1020 strokes/ minute.

REFERENCES

Anonymous. 2008a. www.ficciagroindia.com/general/agriculturestatistics. A site registered with main library, Punjab Agricultural University, Ludhiana (Date of visit: 15th APR, 2009).

Anonymous. 2008b. www.indiastat.com. A site registered with main library, Punjab Agricultural University, Ludhiana (Date of visit: 15th April, 2009).

Bhaholyodin, B., K. Prasarn., K. Kazumoto, and G. Yoshiaki. 1988. Study on some physical properties of sugarcane for whole stalk harvester design. J Kasetsart 22: 88-90.

Briscoc, J. M. 1970. M.F.-201 Trials in Mexico and Jamaica. Sugar Y.Azucar 65(9): 23-24.

Gupta C. P, L. Lwin, and T. Katiwat. 1996. Development of a self-propelled single-axle sugarcane harvester. Trans ASAE 12: 427-34.

Sharma, M. P., S. R. Misra, and A. K. Mishra. 2006. Recent developments in sugarcane mechanization in India. J. Agric Mech Asia Afr Lat Am (AMA) 37: 33-35.

Sharma, M. P. and K. Singh. 1985. Design and development of rear mounted tractor operated sugarcane harvester. J Agric Mech Asia Afr Lat Am (AMA) 16: 47-50.

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—vii congreso ib ricoéde agroingenieria y ciencias hortícolas—

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http://ecplf2013.eu/

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■ Professor Engineer, Ph. Doctor, Professor Emeritus

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Dr. Kushwaha has devoted his entire career in the service of the engineering profession nationally and internationally starting at the Allahabad Agricultural Institute, India in 1961 and continuing at the University of Saskatchewan. He received Ph.D. (1967) from the University of Saskatchewan becoming the first Ph. D. in Agricultural Engineering in Canada. He has been very active with International activities with professional societies and collaborating with universities in Bangladesh, China, India, Tanzania and Trinidad & Tobago. On invitation by the Indian Council of Agricultural Research, he established the Soil Dynamics Research Facility at the Central Institute of Agricultural Engineering, Bhopal. He supervised graduate students from Bangladesh, Brazil, China, Sudan, India, Egypt and Jamaica. His work on soil/tool interaction recognized internationally has been published in a book Soil-Machine Interactions-A finite Element Perspective. With collaborators, he holds three patents.

His area of specialization includes soil-machine interaction that lead to neutralization of antipersonnel landmines. Current research includes applications of biomaterials for replacement of human limbs and joints, biocomposite materials and bio-energy.

Major recognitions include: University of Saskatchewan Alumni Achievement Award (2012); SAE International Recognition for Service to the Technical Quality Response Team (2012); ASABE Kishida International Award (2012); University of Saskatchewan Prime of Life Achievement award (2011); Bharat Gaurav Award (2010); Saskatchewan Centennial Leadership Award (2005); CSBE Maple Leaf Award (2004); ASABE John Deere Gold Medal (2002); The APEGS Distinguished Service Award (1998); The SAE Forest R. McFarland Award (1997); CSBE Glenn Downing Award (1993) and Fellows of ASABE, CSBE, SAE International, ISAE and Engineers Canada.

Service to Engineering Profession includes: President of CSBE/SCGAB for two terms (2001-2003); Member of Board of Trustees of ASABE (2001-03); Executive Council member of CIGR (2004-2009); Member of Canadian Engineering Qualification Board (CEQB) of Engineers Canada (1998-06); Councillor of the Association of Professional Engineers and Geoscientists of Saskatchewan Council (2004-06); also chair of several committees of ASABE, CSBE, APEGS and Engineers Canada; Editor of CSBE Journal; Associate Editor of ASABE Transactions. He is one of the founding members of CSBE Foundation.

Currently, Prof. Kushwaha is Editor-in-Chief: Journal of Terramechanics, member Editorial Board "International Agrophysics" Polish Academy of Sciences, Poland and member International Editorial Advisory Committee "West Indian Journal of Engineering" Trinidad & Tobago.

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Engineering Faculty, Campus Chillan, University of Concepcion, Chile.

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1991. Industrial Engineer, by Engineering Faculty, University of Concepcion. Concepcion. Chile.

2000. Master of Agricultural Engineering, by Agricultural Engineering Faculty, University of Concepcion, Chillan. Chile.

2010. Candidate to Doctoral degree in "Natural and Rural Resources Development in Agricultural, Food and Technological Sciences", in University of Cordoba. Spain. Doctoral thesis title: "Operational, management and economical aspects in the assignation, administration and use of water used for agricultural irrigation in Chile".

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■ **Administrative experience:**

2007. 2011; 2013. date. Head of the Mechanization and Energy Department.

2004. 2007. Vice . dean of Agricultural Engineering Faculty.

1998. 2001. Academic coordinator of Agricultural Engineering career.

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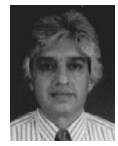
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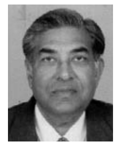
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