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TOKYO

Yoshisuke Kishida, Publisher & Chief Editor

EDITORIAL STAFF
(Tel.+81-(0)3-3291-3674)
Yoshisuke Kishida, Chief Editor
Haruna Iwase, Managing Editor
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ADVERTISING
(Tel.+81-(0)3-3291-3674)
Yuki Komori, Manager (Head Office)
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CIRCULATION
(Tel.+81-(0)3-3291-3674)
(Fax.+81-(0)3-3291-5717)
Editorial, Advertising and Circulation Headquarters
1-12-3, Kanda Nishikicho, Chiyoda-ku, Tokyo 101-0054, Japan
URL: http://www.shin-norin.co.jp/english/
E-Mail: ama@shin-norin.co.jp

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EDITORIAL

First of all, I would like to wish all the readers of AMA a happy new year.

Time flies. 16 years have already passed since the beginning of 21st century. In this narrowing earth, the world population exceeded 7.3 billion and keeps increasing towards 9 billion. In this situation, wars and terrorism are occurring and the earth is not peaceful.

What people need to live is food. Rich and good environment is also needed. Bountiful forests bless beautiful fresh water for people. For producing food, agricultural land has been made by cutting open many forests in the past. A large amount of fossil fuel has been used and carbon dioxide in the atmosphere is increasing. The earth is rapidly entering the era of global warming now. There are international agreements to restrict global carbon dioxide emissions. However, it is very difficult to control. In northern Siberia, frozen soil had melted and caused large ground subsidence, thus a large amount of methane gas that had been asleep at the bottom of frozen soil was discharged into the atmosphere. The temperature gap between ground and the stratosphere has expanded and updraft and downdraft are both becoming fierce. Climate changes such as large-scale typhoons and hurricanes are getting more intense. Farm work needs to be done more speedily by agricultural mechanization.

We cannot keep cutting forests which absorb and fix carbon dioxide anymore. Then we must provide food stably with limited farmland for the growing population. As I have mentioned repeatedly, land productivity must be increased by agricultural mechanization. Now, people move from the countryside to the cities and the population of the cities is rapidly increasing. Reduction in agricultural labor force is occurring in many countries, thus agricultural labor productivity also must be increased by agricultural mechanization. For the future survival of human beings, further progress of agricultural mechanization is essential. In Japan, 80% of agricultural workers are over 60 years old and rapid decrease in labor force is occurring. They will be over 80 years old after 20 years, so we definitely have to make labor productivity 5 times in 20 years. It is really a hard challenge. It is impossible only with extension of conventional mechanical technology. Therefore, realization of new agricultural robots and intelligent machine is essential. For not only Japan but also all over the globe, realization of new agricultural machines by informatization of agricultural machines, unmanned, and advanced use of artificial intelligence is really needed.

When I first published AMA in 1971, discussions on appropriate technologies necessary to promote agricultural mechanization in developing countries were actively conducted. The opinion that we must design easy-to-use, easy-to-make and easy-to-repair machine was very important. However, when we see the present situation that smartphones are rapidly spreading in developing countries...what are appropriate technologies and what machines are appropriate? There is a possibility that small simple agricultural robot be the best machine for developing countries. I think the time has come to rethink together about appropriate technologies for present era.

There are various problems on agricultural machinery. Let's cooperate with each other and challenge to solve them.

Yoshisuke Kishida
Chief Editor

January, 2017

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ERRATA

We published the wrong version of manuscript bearing below mentioned title in Vol. 47 No.4 (p. 47). The right one is as below. We apologize to them and all our readers for our mistakes.

Low Cost Fermenter for Ethanol Production from Rice Straw in Egypt

by
Mohamed A. A. A.
Central Laboratory for Agricultural Climate
Agricultural Research Center
EGYPT
assem20000@yahoo.com

R. K. Ibrahim
Agricultural Engineering Research Institute
EGYPT

M. A. M. Elesaily
Agricultural Engineering Research Institute
EGYPT

Abstract

In Egypt, significant emissions arise caused by rice straw burning on the field. The total amount produced yearly about three million Mg, essential nutrients and organic matter are lost. The combined energy and material utilizations of rice straw can realize an important contribution to climate protection and resource conservation.

To produce bio-ethanol from rice straw, there are four steps that should be taken: 1-Chop rice straw; 2-Mill rice straw; 3-Rice straw sterilization; and 4-Fermentation the milled rice straw in the fermenter using yeast micro-organism.

The present investigation included; manufacture fermenter locally, using computer design software Version 4.0, and techno-economic study using three proposed fermenters scales (300, 600 and 900 litres capacity) at Central Laboratory for Agricultural Climate (CLAC), Dokki, Agricultural Research Center (ARC), Giza, Egypt. A cost-benefit analysis approach was calculated and total return for the three scenarios was estimated for different percentages of ethanol extraction (15, 17 and 20%).

The obtained results indicated that, using fermenter 900 litres capacity (third scenario) for 20% of ethanol extraction was the economical and effective one to produce bio-ethanol appropriate for small growers; where profit value was USD 566. The net present value at discount rate (D.R) of 30% was estimated to be a positive value of USD 1.096. The benefit cost ratio (B/ C) at the same D.R. was estimated to be 1.22; and the internal rate of return (IRR) reached about 30%.

Keywords: Benefit cost ratio, Ethanol, Fermenter, Internal rate of return, Net present value, Net return, Rice straw.

Introduction

Rice straw is approximately 50% of the total weight of rice plants (Putun *et al.*, 2004) by weight the rice straw consist mainly of cellulose and hemicelluloses (74%), lignin (18%), fat (1%) and protein (3%) (Phuong *et.al.,* 2010). The total area of rice crop in Egypt was 0.567 million hectares, with an output of 5.5 million tons rice and about 3

million tons of rice straw in 2014. Only a small amount of rice straw is used to produce bio-fertilizers, cattle feed, and grow mushrooms. The rice straw leftover in the field is burned on the field causing environmental pollution and increasing CO_2 in the air. Therefore, the use of straw resources to produce ethanol will have enormous impact in many aspects, environmentally and economically (MALR, 2014).

Ethanol from biomass has become an increasingly popular alternative to gasoline as one option, to reduce dependence on oil use and mitigate global warming. Bioethanol is commercially produced on a moderate scale (approximately 80 million tons worldwide in 2010). The ethanol mainly produced from sugar cane, corn, and other starchy biomass sources (Balat, M. and H. Balat, 2009).

The production of liquid fuels from ligno-cellulosic materials, with emphasis on ethanol, is being extensively investigated in both developed and developing countries. Most of the studies and early stage applications are directed towards the production of ethanol in large scale facilities of capacities around 15-100 Mm^3/y, taking into consideration the high transport costs especially in rural communities, where lignocellulosic biomass was generated. It seems appropriate to investigate the techno-economics of ethanol production on a relatively small-scale (about 2.8-4.0 Mg/y). Using small- scale ethanol production units from rice straw, as a typical ligno- cellulosic material that is currently an environmental nuisance, is technically and economically viable (Tewfik S. R. *et al.*, 2010).

Produced bioethanol biologically by fermentation from a variety of biomass sources is widely recognized as a unique transportation fuel and original material of various chemical with powerful economic, environmental and strategic attributes (Zhang *et al.*, 2011).

Lignocelluloses are mainly composed of three groups of polymers, namely cellulose, hemicellulose and lignin. Cellulose and hemicellulose are sugar rich fractions of interest for use in fermentation processes, since microorganisms may use the sugars for growth and production of value added compounds such as ethanol (Mussatto and Teixeira, 2010).

Table 1 Rice straw: chemical composition

Component	Rice straw (%)
Moisture	8.4
Ash	19.3
Protein	5.3
Nitrogen	0.8
Cellulose	35
Lignin	12.2
Water Binding capacity	19.0

Source: Central Laboratory for Agricultural Climate (CLAC), CEMUWA project 3145, ARC, Egypt, 2013.

Materials and Methods

In this paper, optimize fermenter design by computer software version 4.0, and techno-economic studies for the ethanol production from rice straw for proposed fermenter scale have been conducted at CLAC laboratory. Technology and process aspects were carried out by 20 kg/day rice straw comprising the processing stages. A benefit-cost analysis approach was the core of getting at the financial reliability of the production of ethanol from rice straw. In that context, measures of net present value (N.P.V), and internal rate of return (IRR) were applied as discounted measures.

The chemical composition of rice straw was presented in **Table 1**.

Machines Selection

Two machines were selected for rice straw chopping. The first machine was designed to chop rice straw size between (10-15 cm), the machine capacity is one Mg/ h. The machine specifications are feeding chute, two feeding drums 20 cm width. Machine drum has six cutting knives; the machine was driven by electric motor 10 kW to overcome rice straw cutting resistance. The second machine equipped with hammer mill drum and fixed knife, machine capacity is 0.250 Mg/ h and equipped by 2 kW electric motor, rice straw sizes were grind from 10-15 cm, to less than 2 mm, the machine was modified by replacing 2 kW, electric motor, and powered by 3.5 kW electric motor, the second modification was milling drum component by using adjustable knifes instead of fixed knife to overcome rice straw cutting, milling and grinding resistance.

Table 2 Chopper and milling machine costs per hour

Equipment	Fixed cost (USD/ h)	Power consumption cost (USD/h)	Total cost (USD)	Operation cost/ton (USD/ Mg)
Chopper (1Mg/h)	1.22	0.5	1.72	1.72
Mill (0.250Mg/h)	0.56	0.11	0.67	2.67

Source: Central Laboratory for Agricultural Climate (CLAC), CEMUWA project 3145, ARC, Egypt, 2013.

Table 3 Material energy consumption and costs

Product	Energy (kW/ kg)	Cost (USD/ Mg)
Chopped rice straw	0.013	1.72
Milled rice straw	0.025	4.39

Source: Central Laboratory for Agricultural Climate (CLAC), CEMUWA project 3145, ARC, Egypt, 2013.

Table 2 lists chopper and milling machine costs per hour, and **Table 3** lists material energy consumption with cost.

Table 4 Total investment costs for small scale fermenter

Items	Capacity		
	300 Litres	600 Litres	900 Litres
Cost of fermenter USD	1.000.00	1.333.33	1.666.67
Administrative fees USD (1%)	10	13.33	16.67
Indirect costs USD (4%)	40	53.33	66.67
Total USD	1.050.00	1.400.00	1.750.00

Fermenter Manufacturing

A fermenter or bioreactors is a container designated to provide an optimum environment in which micro-organisms or enzymes can interact with a substrate and perform the desired products. Batch fermenter design was carried out using fermenter design software version 4.0, and solid state fermentation bioreactor fundamentals of design; also hand- book operation, fermentation monitoring, design, operation and biochemical engineering III course notes. Two fermenters were built as follow: First fermenter 20 litres capacity, with the following features: capacity 20 litres double cool and heat jacket, control panel, electric voltage and temperature indicator. The fermenter has five props to measure solution PH, temperature, dissolved oxygen, pressure outlet and material inlet hole, also, fermenter equipped with three sample valves and drain valve from bottom side. Second fermenter specifications are: capacity 300 litres, double cool and heat jacket to control optimum temperature required by two electric sensors, electric control panel, electric voltage, overload control, fermenter has five props to measure fermenter temperature, materials PH, stirrer and gas out-let, as shown in (**Fig. 1**).

Ethanol Production Process from Rice Straw

Method of ethanol extraction from ligno-cellulosic materials, input materials essentially comprises the following:

- Shredded and milled rice straw;
- Micro-organism strain; and
- Distilled water

The output material comprises the following:

- Ethanol product (raw liquid); and
- Solid material (safe compost).

Proposed Appropriate Small-Scale Capacity Fermenter

Based on this composition and realistic conversion factors, ethanol yield, the annual quantity of ethanol produced and economic factors, the following are three assumptions of fermenter capacity scenarios.

Scenario I: fermenter 300 litres capacity.

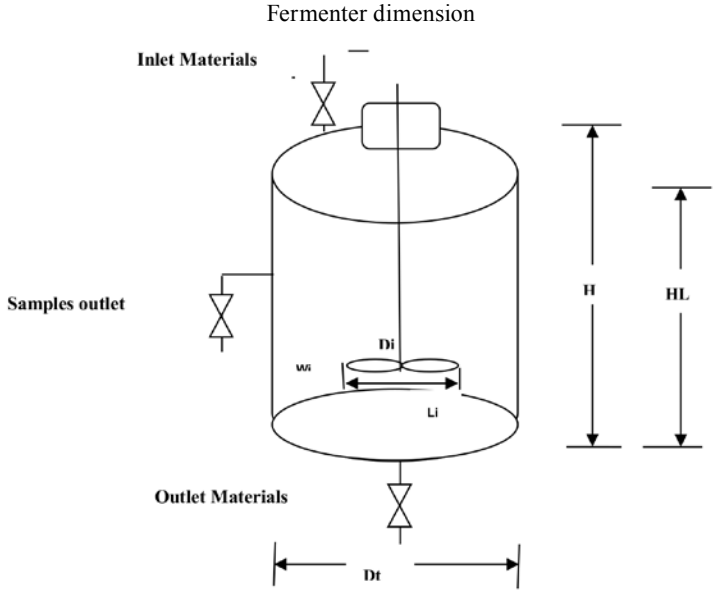
Scenario II: fermenter 600 litres capacity.

Scenario III: fermenter 900 litres capacity.

Results and Discussion

Costs Estimate

The Investment costs have been estimated for available equipment and local prices for the equipment manufactured in 2013.Concerning the assumption of three scenarios the investment costs have been estimated respectively, USD 1.050, USD 1.400 and USD 1.750 as shown in **Table 4**.



Where:
Dt = Tank diameter
H = Fermenter height
HL = Liquid height
Di = Impeller diameter
Li = Impeller blade length
Wi = Impeller blade height

Fig. 1 Fermenter image (300 Liter).

Table 5 Cost analysis of ethanol production from rice straw first scenario (300 litres capacity)

Description	Total needs	Unit price USD	Total price USD	Rank %
Depreciation investment cost			52.44	6.5
Operational costs/ year				
Rice straw (Kg)	5,200	0.02	115.56	15.32
Electricity (watt)	36	0.04	1.4	0.19
Water (litre)	280	0.06	15.56	2.06
Maintenance (1% of capital cost)			10.6	1.41
Workers (man/ day)	27	11.11	300	39.78
Yeast (micro- organism)			311.11	41.25
Total cost (USD)			806.67	100

Table 6 Total return for first scenario (300 litres capacity)

Items	Ethanol extraction %		
	15	17	20
Total production (litre ethanol)	780	884	1.040
Raw ethanol selling Price (USD/litre)	0.44	0.44	0.44
Selling value (USD)	346.67	392.89	462.22
By-product selling value (compost) (USD)	104.44	104.44	104.44
Total cost (USD)	806.67	806.67	806.67
Total return (USD)	451.11	497.33	566.67
Profit/ loss (USD)	-355.56	-309.33	-240.00

Table 7 Cost analysis of ethanol production from rice straw second scenario (600 litres capacities)

Description	Total needs	Unit Price USD	Total Price USD	%
Investment cost depreciation			70.00	7.3
Operational costs/day				
Rice Straw (Kg)	10.400	0.02	231.11	26.00
Electricity (watt)	36	0.04	1.40	0.16
Water (Litre)	560	0.06	31.11	3.50
Maintenance (1% of capital cost)		0.00	14.11	1.59
Workers (man/ day)	27	11.11	300.00	33.75
Yeast (micro- organism)			311.11	35.00
Total cost (USD)			958.89	100

Table 8 Total return for second scenario (600 litres capacity)

Items	Ethanol extraction%		
	15	17	20
Total production (litre ethanol)	1560	1.768	2.080
Raw ethanol selling price (USD/litre)	0.44	0.44	0.44
Selling value (USD)	693.33	785.78	924.44
By- product selling value (compost) (USD)	208.00	208.00	208.00
Total cost (USD)	958.89	958.89	958.89
Total return (USD)	901.33	993.78	1,132.44
Profit/ loss (USD)	(-) 57.56	34.89	173.56

Ethanol Production Costs for Each Scenario:

Operating costs have been estimated according to prevailing prices of rice straw raw materials, micro-organism strain, utilities (water and electricity) and labor. Maintenance cost has been assumed to be 1% of the capital investment of the various cases.

Net ethanol production costs were estimated according to the following parameters: investment costs (depreciation or fixed cost), rice straw costs, fixed operating costs (labor and maintenance costs), and variable operating costs (other materials and energy costs).

Ethanol production cost- first scenario (fermenter 300 litres)

Table 5 reveals that the total cost of ethanol production from rice straw for first scenario is about USD 806.67. The yeast (micro-organism) came in first rank with USD 311.11, which represents about 41.25% of the operational costs, while worker wages came in the second rank being on average 39.78% of the operational costs. Whereas, value of rice straw came in the third rank representing 15.3% of the operational costs. The revenues have been estimated based on the price of raw ethanol in the range of about USD 0.44 for one litre ethanol raw.

Table 6 shows that the total production was 780, 884 and 1.040 litres ethanol, at 15%, 17%, and 20% of ethanol extraction respectively; the selling value estimates of USD 346.67, 392.89 and 462.22 at 15%, 17%, and 20% of ethanol extracted respectively and 3.12 tons compost, with total price USD 104.44, meanwhile, the total return has reached USD 451.11, USD 497.33 and USD 566.67 at 15%, 17%, and 20% of ethanol extracted respectively, the loss was estimated to be USD -355.56, -309.33, -240 at 15%, 17%, and 20% of ethanol extraction, respectively.

Ethanol production cost- second scenario (fermenter 600 litres)

Table 9 Cost analysis of ethanol production from rice straw third scenario (900 litres capacities)

Description	Total needs	Unit price USD	Total price USD	%
Operational costs/day				
Rice straw (Kg)	15,700	0.02	348.89	34.01
Electricity (watt)	36	0.04	1.40	0.14
Water (Litre)	840	0.06	46.67	4.55
Maintenance (1% of capital cost)		0.00	17.67	1.72
Workers (man/ day)	27	11.11	300.00	29.25
Yeast (micro- organism)			311.11	30.33
Total cost (USD)			1,143.56	100

Table 10 Total return for third scenario (900 litres capacity)

Items	% of Ethanol extraction		
	15	17	20
Total production (litre ethanol)	2,355	2,669	3,140
Raw ethanol selling price (USD/litre)	0.44	0.44	0.44
Selling value (USD)	1,046.67	1,186.22	1,395.56
By- product selling value (compost) (USD)	314.00	314.00	314.00
Total return (USD)	1,360.67	1,500.22	1,709.56
Total cost (USD)	1,143.56	1,143.56	1,143.56
Profit (USD)	217.11	356.67	566.00

Table 11 Investment and replacement costs (USD)

Items	No. of units	Price/unit	Cost	Project lifespan (Years)	Replacement (Years)
Fermenter	1	1,666.67	1,666.67	20	-
Land Rent	1	33.33	33.33		-
Administrative fees	-		16.67		-
Indirect costs	-		66.67		-
Total			1,750.00		-

Table 12 Operational costs (USD)

Year	Rice straw cost	Electricity cost	Water cost	Maintenance cost	Labor cost	Yeast cost	Total
1	348.89	1.40	46.67	17.67	300.00	311.11	1,025.78
2	348.89	1.40	46.67	17.67	300.00	311.11	1,025.78
3	348.89	1.40	46.67	17.67	300.00	311.11	1,025.78
4-20	348.89	1.40	46.67	17.67	300.00	311.11	1,025.78

Table 13 Total project cost (USD)

Year	Investment cost	Operating cost	Total cost
1	1,750.00	1,025.78	2,775.67
2	0.00	1,025.78	1,025.78
3	0.00	1,025.78	1,025.78
4-20	0.00	1,025.78	1,025.78

Table 14 Total project return (USD)

Year	Ethanol	By product	Total return
1	1,395.56	314.00	1,709.56
2	1,395.56	314.00	1,709.56
3	1,395.56	314.00	1,709.56
4-20	1,395.56	314.00	1,709.56

Table 7 reveals that the total cost of ethanol production from rice straw in second scenario is about USD 958.89. The yeast (micro-organism) came in first rank with USD 311.11, which represents about 35% of the operational costs, while the worker wages came in the second rank being on average 33.75% of the operational costs. Whereas, value of rice straw came in the third rank representing 26% of the operational costs.

Table 8 shows that the total ethanol production was 1.560, 1.768 and 2.080 litres ethanol, at 15%, 17%, and 20% of extracted ethanol respectively, the selling value estimates was USD 693.33, USD 785.78 and USD 924.44, at 15%, 17%, and 20% of extracted ethanol respectively, also, obtained by product was 6.24 tons of compost, with total price USD 208.00, the total return has reached USD 901.33, USD 993.78 and USD 1.132.44 at 15%, 17%, and 20% of extracted ethanol respectively, while, the profit was estimated to be USD -57.56, USD 34.89 and USD 173.56, at 15%, 17%, and 20% of extracted ethanol respectively.

Ethanol production cost- third scenario (fermenter 900 litres)

Table 9 reveals that the total cost of ethanol production from rice straw in third scenario is about USD 1,143.56. The value of rice straw came in the first rank, with USD 348.89, which represent about 34% of the operational costs; while, the value of yeast (micro-organism) came in the second rank being represented by 30.3% of the operational costs. Whereas, worker wages came in the third rank represent 29.25% of the operational costs.

Table 10 shows that the total production was 2.355, 2.669 and 3.140 litres of ethanol, at 15%, 17%, and 20% of ethanol extraction respectively; with the selling value estimates of USD 1.046.67, USD 1.186.22 and USD 1,395.56 at 15%, 17%, and 20% of extracted ethanol respectively, also, obtained 9.42 tons of compost, with total price USD 314.00. The total return has reached USD 1,360.67, USD 1,500.22 and USD 1,709.56 at 15%, 17%, and 20% of extracted ethanol respectively; therefore, the profit was USD 217.11, USD 356.67 and USD 566.00, at 15%, 17% and 20% of extracted ethanol respectively.

Financial Analysis for Third Scenario (20% ethanol)

Financial analysis was carried out to measure the project profitability in **Tables (11-14)**, respectively.

Results of financial analysis

- The net present value at discount rate (D.R) of 30% was estimated to be a positive value of USD 1,096;
- The benefit cost ratio (B/ C) at the same D.R. was estimated to be 1.22; and
- The internal rate of return (IRR) reached about 30%.

Conclusions

To produce bioethanol from rice straw, the following steps should be conducted, rice straw should be chopped and milled using two different machines, then rice straw were grinded should be sieved into 4 sizes (10-15, 5-10, 2-5 and less than 2 cm).

There are three scenarios for different fermenter volumes (300, 600 and 900 litres capacity) and different percentages of ethanol extraction (15, 17 and 20%). The economic scenario is fermenter 900 litres capacity (third scenario).

The expansion and development of the bioethanol from rice straw will have positive developmental impacts on the economy, the people and the environment in Egypt. All these results indicate there are promising investment opportunities, and the projects could be a great success, if well managed for scenario II (600 litres capacity) and scenario III (900 litres capacity).

There is a need to increase the percentage of bioethanol production from rice straw, for the betterment of national economy, efficient use of local funds, increase of employees and decrease of noxious emissions of CO^2 and N^2O.

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Shearing Characteristics of Sorghum Stalk

by
Mrudulata Deshmukh
Assistant Professor
Department of Farm Power and Machinery
Dr. Panjabro Deshmukh Krishi Vidyapeeth
Akola - 444104
INDIA
mrudulatad@rediffmail.com

S. K. Thakare
Assistant Professor
Department of Farm Power and Machinery
Dr. Panjabro Deshmukh Krishi Vidyapeeth
Akola - 444104
INDIA
drskthakare@rediffmail.com

S. W. Jahagirdar
Associate Professor
Department of Economics and Statistics
Dr. Panjabro Deshmukh Krishi Vidyapeeth
Akola - 444104
INDIA

Abstract

Shearing characteristics of Sorghum (Sorghum bicolor L. Moench) stalks of three varieties CSV-20, CSV-23 and CSH-9 were determined at upper, middle and lower sections of the stalk using Food Texture Analyzer. The stalk specimens were deformed in a quasi-static process at two loading rates (50 mm/min and 75 mm/min). The cutting force required for shearing of sorghum stalks, ultimate cutting stress and specific shearing energy were determined at three sections for three varieties. The mean of the force required for cutting upper section of stalk of all varieties at first and second loading rate was 241.66 and 243.83 N respectively. The Ultimate cutting stress at upper section of stalk for the variety CSV-20 at the first loading rate found more by 12.03% as compared with the second loading rate. The UCS was found 35.13% and 36.35% more at 75 mm/min loading rate for the varieties CSV-23 and CSH-9 respectively. The mean values of cutting force required for middle section of stalk recorded as 303.36 N and 307.42 N respectively at first and second loading rate. The ultimate cutting stress at middle section of stalk for the variety CSV-20 at first loading rate was increased by 33.42% as compared with the second loading rate. The value of UCS was slightly increased by 6.81% in case of the variety CSV-23. The trend of UCS was observed reverse for the variety CSH-9. The Specific Shearing Energy had increasing trend for the variety CSV-20 as the loading rate is increased from 50 mm/min to 75 mm/min. However, the reverse trend of SSE was observed in case of the varieties CSV-23 and CSH-9 for middle section of the stalk. The mean of the force required for cutting lower section of stalk of all varieties at first and second rate of loading was 358.58 and 541.92 N respectively. The Ultimate cutting stress had increasing trend for all three varieties as the rate of loading is increased from 50 mm/min to 75 mm/min for lower section. The Specific Shearing Energy had increasing trend for the variety CSV-20 & CSV-23 as the loading rate is increased from 50 mm/min to 75 mm/min.

Introduction

The India covers 34% of the total Sorghum area in the world and produces around 17% of the world production of sorghum grain per annum. It is being cultivated in Maharashtra for both grain and fodder during kharif (area 13.84 lakh ha) and rabi (area 30.17 lakh ha). Sorghum is second largest growing crop of Vidarbha region of Maharashtra. Important mechanical properties of the cellular forage material from the cutting standpoint are strength in tension, shear and bending. These properties are influenced by species, variety and age of the plant, moisture content and the cellular structure (Person, 1987). It is also necessary to determine the physico mechanical properties such as shearing stress and energy requirement to design suitable cutting devices and optimise operational parameters.(Ince *et al.*, 2005). The mechanical properties of sorghum

stalk are essential for the design of equipment and analysis of the behavior of product during agricultural process operations such as harvesting, handling etc. The cutting of stalk is an important process in sorghum harvesting, forage harvesting, weeding, stalk shredding etc. The properties of the cellular material that are important in cutting are compression, shearing, density and friction (Taghijarah *et al*., 2011). In view of above the study was undertaken with the objective, to determine the effect of loading rate on shearing characteristics namely cutting force (CF), ultimate cutting strength (UCS) and specific shearing energy (SSE) of sorghum stalk.

Materials and Methods

The experimental material selected for the study was three different varieties CSV-20, CSV-23 and CSH-9 of sorghum planted in the year 2012 on the experimental field at Western Block of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. Stalks of physiologically matured sorghum plants were selected and the experiment to determine CF, UCS and SSE was conducted at upper, middle and lower position of stalk.

Moisture Content

The moisture content of the sorghum stalk was measured according to ASAE Standard S.352 (ASAE Year Book 1979). The sample of stalk was kept in an oven for 24 hours at 105°C. The loss in weight of the sample was recorded and the moisture content in percent was determined by using following equation.

$M.Cwb = (Wi - Wd / Wi) \times 100$

Where,

M.Cwb = Moisture content, % wb

Wi = Initial weight of sample, g

Wd = Dried weight of sample, g

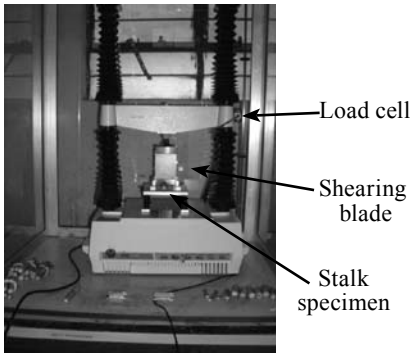

Plate 1 Food Texture Analyzer

Stalk Diameter

The Sorghum stalk diameter was determined with the help of a slide calliper having a least count of 0.01mm. Three repeated measurements were taken for upper, middle and lower sections to get average value.

Experimental Techniques

The quasi static shearing tests were conduced using Food Texture Analyzer (**Plate 1**) to determine shearing force for the sorghum stalk. The machine consists mainly of a shearing blade, rigid fixture on the base platform to keep the stalk specimen and a load cell of capacity 250 kg for recording the shearing force. Data chart recorder where the live graph of each test can be observed seperately as well as the tabular data can be recorded in the format of excel sheet. Two loading rates 50 mm/min and 75 mm/min were selected for the study. The stalk samples were kept on the fixture. During the downward movement of the crosshead, the knife cuts the specimen by shear and passed through the slots provided in the fixture below the specimen. The force required for shearing stalk at the crosshead speed of 50 and 75 mm/min. was recorded against time on the chart recorder. The indices which determine the shearing behavior of the plant material are ultimate cutting stres and specific shearing energy.

The Ultimate cutting stress is expressed by

$\sigma_s = F_{max} / A$

where, σ_s is the ultimate cutting stres, F_{max} is the maximum shear force (N) and A is the cross-sectional area (mm2)of the stalk. Based on the performed measurements of shearing force, the specific shearing energy was calculated as a quotient of the total strain energy and the stalk cross sectional area. (Chattopadhayay and Pandey, 1999).

$Ess = F / A \int dx$

Where,

Ess = Specific shearing energy, mJ/mm^2,

F = Shearing force, N

A = Cross section of sample at the place of cutting, mm^2,

x = Travel of knife (displacement), mm.

Variables for the Study

Independent variables:

I) Varieties - 3 (CSV-20, CSV-23 & CSH-9)

II) Rate of loading (RL) - 2 (50 mm/min, 75 mm/min.)

Dependent variables:

I) Cutting force

II) Ultimate cutting stress III) Specific shearing energy

Replications: 3

Design: Split Plot Design

The samples for investigations were collected at random. The stalks of an average equal diameter were selected for the experimentation. Three samples were prepared from upper, middle and lower section of the stalk for the repetation of the experiment. The experiment was planned on the same day to avoid the fluctuation in the moisture content of the stalk.

Results and Discussion

The shearing strength of stalk for the varieties CSV-20, CSV-23 and CSH-9 at upper, middle and lower sections were determined with 50 mm/min and 75 mm/min rates of loadings. The diameters of sample stalks selected for determination of shear force for all three varieties

Table 1 Cutting force for upper section of stalk

Particulars	Cutting Force, N		Mean
Variety	Rate of loading		
	50 mm/min.	75 mm/min.	
CSV-20	321.51	260.93	291.22
CSV-23	192.51	193.10	192.81
CSH-9	210.96	277.47	244.22
Mean	241.66	243.83	
	Main Factor (A)	Sub Factor (B)	Interaction
F Test	S	NS	NS
SE (m)±	21.522	33.010	57.175
CD (5%)	84.490	--	--

Table 2 Cutting force for middle section of stalk

Particulars	Cutting force, N		Mean
Variety	Rate of loading		
	50 mm/min	75 mm/min	
CSV-20	419.94	470.24	445.09
CSV-23	286.94	277.05	281.99
CSH-9	203.20	174.98	189.09
Mean	303.36	307.42	
	Main Factor (A)	Sub Factor (B)	Interaction
F Test	S	NS	NS
SE (m)±	59.013	20.302	35.163
CD (5%)	231.673	--	--

were in the range of 7.0 to 9.4mm for upper section, 9.3 to 14.4 mm for middle section and 10.3 to13.9 mm for lower section of the stalks. The moisture content of the stalk ranged from 14.21% to 22.87% for all the varieties.

Characteristics of Upper Section of Stalk (Table 1)

The mean of the force required for cutting of all varieties at 50 mm/min and 75 mm/min rate of loading was 241.66 and 243.83 N respectively and statistically found non significant. When the effect of rate of loading on individual variety was compared, the significant differnce was observed in the values of cutting force with minimum of 192.81 N and maximum of 291.22 N for the variety CSV-23 and CSV-20 respectively. The intermediate value of cutting force 244.22 N was observed for variety CSH-9. The interaction of the mean forces for individual variety and mean forces for all three varieties at 50 and 75 mm/min rate of loading was observed nonsignificant.

The ultimate cutting stress (**Fig. 1**) at upper section of stalk for the variety CSV-20 at the loading rate of 50 mm/min was found more by 12.03% when compared with the loading rate of 75 mm/min. while the trend of UCS was observed reverse for the remaining two varieties CSV-23 and CSH-9. The UCS was found 35.13% and 36.35% more at 75 mm/min loading rate for the varieties CSV-23 and CSH-9 respectively.

The specific shearing energy (**Fig. 2**) for the variety CSV-20 was found 24.76% more at the loading rate of 50 mm/min as compared to 75 mm/min. However, the reverse results were obtained in values of SSE for varieties CSV-23 and CSH-9. It was found that the value of SSE for varieties CSV-23 and CSH-9 was 10.10% and 27.05% more at 75 mm/min loading rate as compared to the values of 50 mm/min rate of loading for upper section of stalk.

Characteristics of Middle Section of Stalk (Table 2)

The cutting force required for all three varieties recorded significant difference in the mean values of 303.36 N and 307.42 N at the rate of loading of 50 mm/min and 75 mm/min when the effect of loading rate was studied on each variety individually, the statistical significant difference was observed in the mean values of variety CSV-20 (445.09 N), CSV-23 (281.99 N) and CSH-9 (189.09 N) when compared with each other. The interactions of the mean forces for individual variety and mean forces for all three varieties at the rate of loading of 50 mm/min and 75 mm/min was observed non significant.

The Ultimate cutting stress (**Fig. 3**) for the variety CSV-20 at the loading rate of 75 mm/min was increased by 33.42% when compared with the values of UCS at loading rate of 50 mm/min. The value of UCS was found slightly increased by 6.81% in case of the variety CSV-23. The trend of UCS was observed reverse for the variety CSH-9 and found decrease in value by 14.56% when the loading rate was increased from 50 mm/min to 75 mm/min.

The specific shearing energy (**Fig. 4**) increased by 31.52%trend for the variety CSV-20 as the loading rate

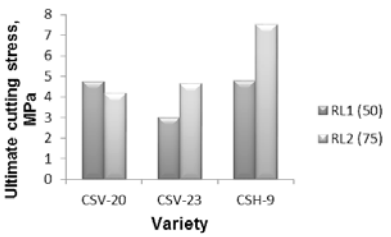

Fig. 1 Ultimate cutting stress for upper section of stalk

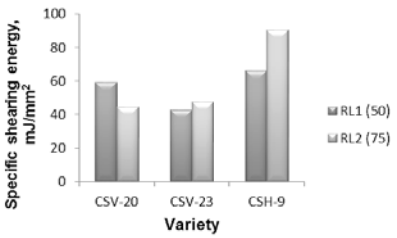

Fig. 2 Specific shearing energy for upper section of stalk

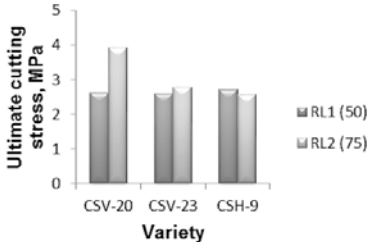

Fig. 3 Ultimate cutting stress for middle section of stalk

Table 3 Cutting force for lower section of stalk

Particulars	Cutting force, N		Mean
Variety	Rate of loading		
	50 mm/min	75 mm/min	
CSV-20	413.06	839.43	626.24
CSV-23	301.70	512.67	407.19
CSH-9	360.97	273.67	317.32
Mean	358.58	541.92	
	Main Factor (A)	Sub Factor (B)	Interaction
F Test	S	NS	NS
SE (m)±	84.505	103.105	178.584
CD (5%)	331.754	--	--

Table 4 Ultimate cutting stress of stalk

Particulars	Ultimate cutting stress, MPa					
Variety	Plant Section					
	Upper section		Middle section		Lower section	
Rate of Loading	50 mm/ min	75 mm/ min	50 mm/ min	75 mm/ min	50 mm/ min	75 mm/ min
CSV-20	4.74	4.17	2.61	3.92	2.89	6.30
	(12.03%)			(33.42%)		(54.13%)
CSV-23	3.01	4.64	2.60	2.79	2.36	5.29
		(35.13%)		(6.81%)		(55.38%)
CSH-9	4.78	7.51	2.71	2.57	2.82	3.09
		(36.35%)	(14.56%)			(8.74%)

Table 5 Specific shearing energy of stalk

Particulars	Specific shearing energy, mJ/mm2					
Variety	Plant Section					
	Upper section		Middle section		Lower section	
Rate of Loading	50 mm/ min	75 mm/ min	50 mm/ min	75 mm/ min	50 mm/ min	75 mm/ min
CSV-20	59.24	44.57	36.5	53.3	45.96	100.97
	-24.76%			-31.52%		-54.48%
CSV-23	42.57	47.35	38.37	36.27	31.76	77.02
		-10.10%	-5.49%			-58.76%
CSH-9	65.97	90.43	34.71	30.59	40.09	40.17
		-27.05%	-11.87%			-0.20%

is increased from 50 mm/min to 75 mm/min. However, the reverse trend of SSE was observed in case of the varieties CSV-23 and CSH-9. The value of SSE decreased by 5.49% for CSV-23 and by 11.87% for the variety CSH-9 when the loading rate was increased from 50 mm/min to 75 mm/min.

Characteristics of Lower Section Of Stalk (Table 3)

The mean of the force of all varieties at 50 mm/min and 75 mm/min rate of loading was 358.58 and 541.92 N respectively and statistically found non significant. When the effect of rate of loading on individual variety was compared, the significant difference was observed in the values of cutting force with minimum of 317.32 N and maximum of 626.24 N for the variety CSH-9 and CSV-20 respectively. The intermediate value of cutting force 407.19 N was observed for variety CSV-23. The interaction of the mean forces for individual variety and mean forces for all three varieties at 50 and 75 mm/min rate of loading was observed nonsignificant.

The ultimate cutting stress (**Fig. 5**) was found increasing for all three varieties as the rate of loading was increased from 50 mm/min to 75 mm/min. The increase in the value of UCS was maximum for the variety CSV-23 (55.38%), followed by the variety CSV-20 (54.13%) and the variety CSH-9 (8.74%) at the loading rate of 75 mm/min as compared to the values at loading rate of 50 mm/min.

The value of SSE increased by 54.48% and by 58.76% for the variety CSV-20 and CSV-23 respectively at the loading rate of 75 mm/min for lower section of stalk. The values of SSE were at par for both loading rates in case of variety CSH-9. The variety CSV-20 recorded maximum specific shearing energy followed by the variety CSV-23 while the variety CSH-9 had minimum value of SSE.

The abstract of ultimate cutting stress and specific shearing energy for thee varieties, two loading rates and three sections are presented in the **Table 4** and **5** respectively.

Values in parenthesis shows per cent increase over other loading rate.

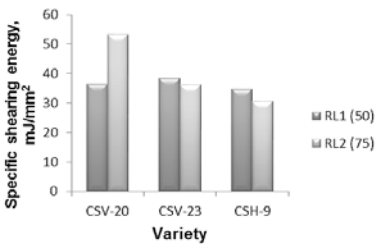

Fig. 4 Specific shearing energy for middle section of stalk

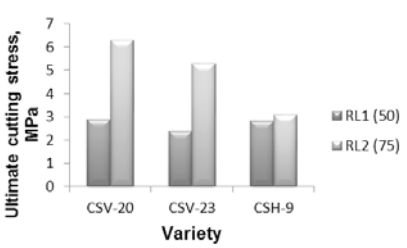

Fig. 5 Ultimate cutting stress for lower section of stalk

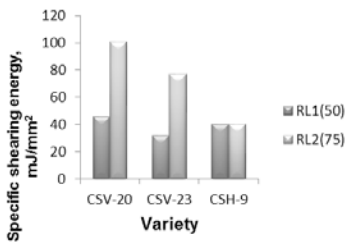

Fig. 6 Specific shearing energy for lower section of stalk

Conclusions

1. The mean of the force required for cutting upper, middle and lower section of stalk of all varieties at 50 mm/min was 301.2 N and 75 mm/min loading rate was 364.39 N respectively.
2. The ultimate cutting stress has decreasing trend for variety CSV-20 upper section of stalks as the loading rate was increased from 50 mm/min to 75 mm/min. For middle and lower section of stalk the trend of UCS was reverse. In case of varieties CSV-23 and CSH-9, the values of UCS had increasing trend for all three sections of stalks.
3. The specific shearing energy for the variety CSV-20 had decreasing trend, while the value of SSE for varieties CSV-23 and CSH-9 increased as the loading rate was increased from 50 mm/min to 75 mm/min for upper section of stalk.
4. For middle section of the stalks, the SSE had increasing trend for the variety CSV-20 as the loading rate is increased from 50 mm/min to 75 mm/min. However, the reverse trend of SSE was observed in case of the varieties CSV-23 and CSH-9.
5. For lower section of stalks the SSE had increasing trend for all three varieties.

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Design of a Portable Dates Cluster Harvesting Machine

by
Ahmed NOURANI
Scientific and Technical Research Centre for Arid Areas (CRSTRA), Biskra
ALGERIA
nourani83@gmail.com

Ferhat KACI
National High School of Agronomy, Algiers
ALGERIA

Francesco GARBATI PEGNA
Department GESAAF
University of Firenze
section biosystems engineering, Firenze
ITALY

Ahmed KADRI
Institute of Agricultural Sciences, Hassiba Benbouali University, Chlef
ALGERIA

Abstract

The dates harvesting is one of the most important farming operations. In Algeria, this practice is still carried out manually by climbing up the tree, but this operation is expensive and there is lack of skilled workers, also because of the increasing number of palms due to the new plantings that have been going on in the past years. Algerian farmers cannot afford expensive machinery such as motorized elevators so the problem has been addressed by developing a manual aid that allows to carry out this operation easily and safely.

This harvesting aid, which includes four components, namely: stabilizing platform, lifting device, lowering device and cutting device, can be carried around manually and fixed at the base of any palm trunk and used to cut and lower whole clusters without having to climb the palm.

The trials that have been carried out show that with the use of this device a cluster at a height of 6.5 m can be picked and lowered in about 3 minutes after the gear has been set.

Keywords: Date palm, mechanization, harvesting, manual device, dates cluster, portable harvester, telescopic mast, supported by the trunk.

Introduction

In Algeria, the date palm is one of the most important crops. It is a source of revenue for about 3.5 million inhabitants in the Saharan regions of the country. According to the Ministry of Agriculture (2006), there are more than 17 million palm trees spread over on area of 154,000 hectares and the total production reaches 500,000 t/year. Algeria is famous for the production of Deglet Nour from Biskra Province.

Date palm requires particular care especially at the level of the crown, such as de-thorning, pollination, spraying, thinning, pruning, clusters arrangement and positioning of anti-breakage-supports, covering and, finally, harvesting. All these operations are still carried out manually, which requires a lot of time and cost, as well the danger of palm climbing.

Several researches have been developed to mechanize some of these operations such as pollination (Perkins *et al.*, 1974; Ibrahim *et al.*, 1987; Yahia, 2009; Mostaan *et al.*, 2010), pruning (Ismail et al, 2006), de-thorning (Mosttan, 2005) and spraying (Abass Hamza *et al.*, 2006; Shapiro *et al.*, 2009). Also several systems for elevating the workers to the crown level have been developed (Abdalla *et al.*, 1986; Hassan *et al.*, 1986; Al-Sohaibani *et al.*, 1987; Bankhar and al., 1995; Wolfgang, 2003; Moustafa, 2005; Keramat *et al.*, 2008; Garbati P., 2008).

Since harvesting is one of the most important operations, a study to improve its efficiency and safety

has been carried out at the Scientific and Technical Research Centre for Arid Areas (CRSTRA) of Biskra and is presented in this paper. Actually harvesting is done manually, by a worker, which climbs up the palm trunk and reaches the crown with the aid of belt and rope, cuts the cluster with the use of a sickle and then lowers it carefully with a rope. This operation is tiring and dangerous so, the objective of this study is to address these constraints through the design and the development of a portable date manual harvesting machine that allows the operator to reach, cut and lower the clusters without climbing up the tree.

Materials and Methods

In this study, a survey of typical date palm farms was carried out on 37 orchards in the Biskra province due to its importance in Algerian date production. The survey revealed:

- In most of the farms visited, the use of a machine, similar to the one developed by Al-Suhabani (1990), is difficult and sometimes impossible due to the presence of an irrigation network and to the little distance of the trees on the row and between the rows.
- In some cases the crown of the date palm can reach up to 14 m of height, but in 83% of productive trees it does not exceed 8.
- No machine is used in the crown-related operations.
- The decreasing availability of skilled labor (climbers) in face of the increasing number of trees and the high cost of the harvesting operation is considered a most constraint for the farmers.
- In all orchards visited, the operation of clusters arrangement and positioning of anti-breakage-supports is considered very important, especially for cultivars with high commercial value. In this operation, the clusters have to be arranged under the leaves so, when growing up in size, fruits will not get caught in the foliage or damaged by thorns. When arranging the clusters, it's often necessary to support them with leaves, since they are not self-sustained. This operation facilitates the rest of the farmer operation like the coverage and harvesting of cluster (Garbati, 2008).

In the light of these observations the main characteristics of the harvesting aid were defined:

- manually operated by one single operator
- easy to transport
- easy to construct and repair in an averagely equipped blacksmith workshop
- minimized use of non-manual power
- capable of working in any kind of plantation layout and soil conditions
- capable of reaching clusters up to 8 m high
- capable of cutting the cluster's stalk and collecting and lowering the cluster to the ground
- economically acceptable in date palm cultivation economy

A first design, done by Nourani using a SolidWorks software, was successively refined and turned into a 1:3 scale aluminum and teflon prototype in the workshop of the GESAAF Department in collaboration with Garbati Pegna and his team. The prototype was then improved with the same software and finally the full size prototype was constructed in the welding workshop of private welder in Biskra town. The materials used are ordinary steel, iron wire, winches and rechargeable electric chain saw.

Fig. 1 Harvester in the field

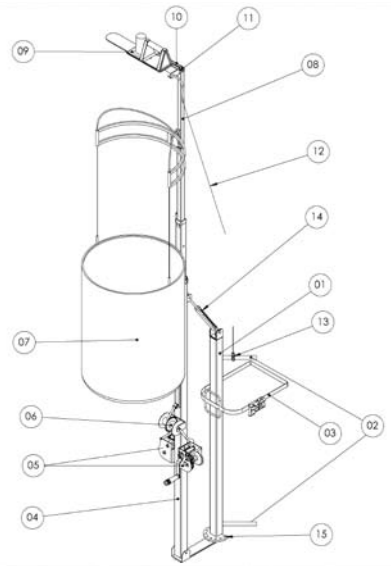

Fig. 2 Diagram of the harvester

01	Stabilizing plaeform	06	Reel	11	Draw wire
02	Feet	07	Basket	12	Return spring
03	Lashing belt	08	Basket support	13	Switch
04	Telescopic mast	09	Electric saw	14	Adjuster
05	Winches	10	Arm to support teh saw	15	Mast fixiing mechanism

Results and Discussions

A. Description

As shown in the **Figs. 1** and **2**, the harvesting aid compounds four principal elements, namely:

1. Stabilizing platform

It is built to support the other components. It is attached vertically directly on the trunk of the palm. It secures the fixation and stability of the machine during the work by two arches and a lashing belt.

2. Lifting/lowering device

It is a telescopic mast extendable with the use of reel and cables actioned by two manual winches and supported by the platform with two mobile joints to make it mobile and fixable. This device is used to raise and lower the cutting device and the basket.

3. Basket

The basket is needed for containing the cluster and allowing it to be lowered without damage. It is made by a metal ring holding a textile bag. It is mounted through the basket support at the upper end of the telescopic mast.

4. Cutting device

This is a rechargeable electric chain saw mounted on an articulated arm, equipped with a return spring and a draw wire. This device is mounted at the upper end of the basket support.

B. Operation

1. Setting

The platform is leaned vertically to the base of the trunk so that the two arches are well in contact with it and the lashing belt is tightened. The lower end of the platform must be well above the ground in order to allow the telescopic mast to rotate freely.

2. Extension

The telescopic mast is extended by means of the winches and at the same time the rigging screw (adjuster) is loosened so that the cluster enters into the basket and electric saw is in the appropriate position. The mast is then fixed by aligning the hole of the lower articulation with a suitable hole of the platform and inserting a pin in the holes.

3. Harvesting and collection

When the cluster is in the basket and the saw is correctly positioned the saw is turned on by the operator with the use of a remote control switch and moved towards the stalk with its draw wire; the cluster then falls into the basket and the basket is let down along the reel by the operator.

This step is repeated for all the clusters of the same part of a plant then the equipment must be placed on the other side. When finished the mast must be lowered for transporting to another plant.

C. Performance and Evaluation of the Machine

The harvesting aid that has been developed has proofed to allow one single operator to harvest all the clusters of a palm tree by placing the equipment on two different sides of the trunk. This equipment weights about 42 kg and can hence be transported around the farm manually or with a wheelbarrow; the cost of constriction is 1,300 euro which makes it affordable for the farmers. This machine can harvest clusters to 8 m of height.

This device was developed after the harvesting season; despite this some farmers leave some clusters in the tree due to bad quality of fruits. Therefore, a test has been carried out to cluster on 6.5 m of height. It was found that the installing of the machine on trunk takes about 6 minutes. Once, the platform has been attached to the tree, it takes about 15 second to extend the telescopic mast comfortably appropriate height, however the setting took 2 minutes, while the time of harvest, come down the cluster and emptying the basket take about 30 seconds, while the transport of the machine from tree to other required in around to 2 minutes. Theoretically, one operator is sufficient to run the machine, but makes it easier for the existence of an assistant is needed.

Conclusions

The machine that has been developed allows harvesting whole date clusters from the ground, without need for the operator to climb up the tree, hence avoiding fatigue and risks consequent to this operation, and can represent an interesting device for farmers to face lack of skilled labor. The time needed for harvesting and its cost make it an affordable alternative to manual harvesting and can represent the link pin between manual and mechanical motorized harvesting.

It is possible to use the telescopic mast as a support to devices for other farmer operations related to the crown of the palm date tree.

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Development of a Paddle Wheel Aerator for Small and Medium Fish Farmers in Nigeria

by
Omofunmi O. E.
Dept. of Agricultural and Bio-Environmental Engineering
Yaba College of Technology
Yaba- Lagos
NIGERIA
omofunmieric@yahoo.com

Adewumi J. K.
Dept. of Agricultural Engineering
Federal University of Agriculture
Abeokuta
NIGERIA

Adisa A. F.
Department of Agricultural Engineering
Federal University of Agriculture,
Abeokuta
NIGERIA

Alegbeleye S. O.
Department of Fisheries and Aquaculture
Federal University of Agriculture
Abeokuta
NIGERIA

Abstract

Pond aeration systems were developed to sustain large quantities of fish and biomass materials. In this study the importance and functions of aeration were examined and prototype paddle wheel aerator was developed. The main features of the paddle wheel aerator were electric motor used as prime mover which was of one horse power capacity, and paddle hubs with six paddles all mounted on a shaft made of stainless steel and brass materials. Aeration experiment was conducted in water basin made up of plastic. Paddle-wheel aerator performance evaluation was conducted using unsteady state test. Physico-chemical properties of water sampled from the tested ponds were determined in accordance with the American Public Health Association standards (APHA, 2005). Performance test carried out showed that the overall oxygen transfer co-efficient (K_La) was observed to be as high as 8.19 hr^{-1} and standard oxygen transfer rate (SOTR) and standard aerator efficiency (SAE) ranged from 1.1-1.2 kg $O^2\,hr^{-1}$ and 1.1-1.3 kg $O^2\,kW^{-1}\,hr^{-1}$ respectively. The paddle wheel aerator improved the water quality by addition of oxygen leading to appreciable increase in the fish stock density which has been a major setback of low-income fish farmer in Nigeria.

Keywords: Oxygen dissolved, overall oxygen transfer coefficient, paddle wheel aerator standard aeration efficiency, standard oxygen transfer rate, water basin

Introduction

During the past decade, pond aeration systems have been developed which will sustain large quantities of fish and invertebrate biomass. These aeration systems are modifications of standard wastewater aeration equipment. Paddle-wheel aerator is surface aeration system which can be vertical shaft or horizontal shaft that producing a large air-water interface the transfer of oxygen from atmosphere is enhanced. The importance and functions of aeration process is hereby highlighted by some investigators like Boyd (2001, 2003); Omofunmi, 2014; Tucker 2005, and Tucker and Robinson, 1990) include:

- it reduces the concentrations of ammonia, nitrites and carbon (iv) oxide
- it increases pH level of pond water.
- it increases the carrying capacity of an aquaculture system.
- it reduces fish mortality.
- it enhances fish reproduction systems
- it reduces level of salinity especially during time of low rainfall
- it increases pond productivity.
- it increases fish growth.
- it regulates water temperature especially as this can affect dissolved oxygen (DO) of aquatic.
- it is used to control thermal strati-

Table 1 Material Selection

Machine part	Material
Base	Iron
Paddle wheel Shaft	stainless steel
Paddle	Stainless steel
Shaft	Brass
Contrl box	Brass
Paddle hub	Stainless steel
Motor	Brass
Gear box	Brass
Motor support	Iron

fication and

- it prevents eutrophication in fish ponds

Types of aerators are:

1) Gravity Aerator: In gravity aerators, water is allowed to fall by gravity such that a large area of water is exposed to atmosphere, sometimes aided by turbulence.
2) Fountain Aerators: These are also known as spray aerators with special nozzles to produce a fine spray.
3) Injection or Diffused Aerators: It consists of a tank with perforated pipes, tubes or diffuser plates, fixed at the bottom to release fine air bubbles from compressor unit.
4) Mechanical Aerators: These may be paddles or spiral types, it increases interfacial area by spraying water droplet into the air. Paddles may be either submerged or at the surface.

Out of these aerators, the mechanical surface aerators are widely used because they offer better efficiency as well as convenience in operation and maintenance. Oxygen transfer rate from gas to liquid phase for paddle-wheel aerator is functions of variables such as speed, mixing intensity and turbulence, geometrical variables such as size and number of paddles, arrangement of the paddles, depth of flow and physicochemical properties of the liquid. American public health association (APHA, 2005) states that for proper mixing of dissolved oxygen (DO) throughout the water volume, the power-to-volume ratio should lie within 0.01-0.04 kW/m^3. Boyd (1998) highlighted that aeration-performance testing has been found important in selecting design features to provide cost-effective yet efficient aquaculture pond aerators. Paddlewheel aerators and propeller-aspirator-pumps are probably most widely used in fish cultures. Boyd (1998) reported that paddlewheel aerators constructed according to, or similar to, a design by Ahmad and Boyd (1988) had the highest standard oxygen transfer rate (SOTR) and standard aerator efficiency (SAE) values. The values for SOTR ranged from 17.4 to 23.2 kg O^2 h^{-1} and values for SAE (based on (shaft power) ranged from 2.6 to 3.0 kg O^2 $W^{-1}h^{-1}$. Aeration performance tests in tanks (Boyd and Ahmad, 1997) indicate that paddle wheel aerators were more efficient in transferring oxygen and circulating water than other types of aerators commonly used in aquaculture. Rappaport *et al.* (1996) made pond tests of several aeration systems (paddle wheels, aspirator, vertical pump, and diffused-air), found that paddle wheel aerators were much more efficient than the other types. Ahmad and Boyd (1988) developed a highly efficient design for 3-10-hp paddle wheel aerators. This design has been used by several companies to manufacture 3-, 5-, and 10-hp aerators and many aerators of similar design are used in commercial channel catfish ponds in the Southeastern United States. Boyd and Ahmad (1997), and Moore and Boyd (1992) highlighted that aquacultural research is often conducted in small ponds of 500-5000 m^2 in area and small ponds are also used in some types of commercial aquaculture. Aerators of 0.25-2 hp are often used in smaller ponds. Small paddle wheel aerators (1 and 2 hp) are made in Taiwan and sold worldwide for use in small ponds. These units are widely used because they are available and relatively inexpensive, but they are not very durable and their oxygen-transfer efficiency is low (Boyd and Ahmad, 1987). They often create excessive water turbulence and turbidity in earthen ponds less than 1,000-1,500 m^2 in area. Attempts to produce small, highly

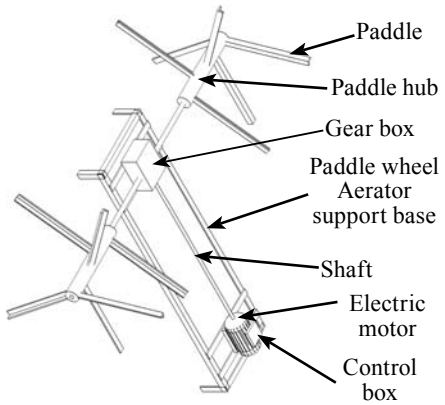

Fig. 1.1 Isometric drawing of paddle wheel aerator

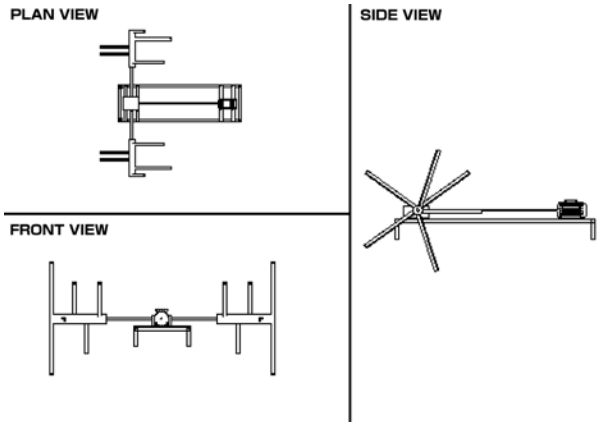

Fig. 1.2 Orthographic drawing of paddle wheel aerator

efficient paddle wheel aerators using design features provided by Ahmad and Boyd (1988) for larger aerators have not been very useful. Electric paddle wheel aerators are widely used in pond aquaculture.

Paddlewheel are commonly used in fish culture and is one of the major capital cost item in the farm. The primary goal of this study was to develop a low cost prototype paddle wheel aerator for catfish production using locally available suitable materials for small to medium scale fish ponds in Nigeria.

Materials and Methods

Material Selection

The materials selected were as presented in **Table 1**. Isometric and orthographic projections of a paddle wheel aerator are presented in **Fig. s 1.1** and **1.2** respectively. The pictures of the aerator are shown in **Fig.s 2.1** and **2.2**.

The choice of components used for this project was based on the following factors:

(1) Simplicity of design,
(2) Cost-effectiveness
(3) The major material used for the fabrication of essential components of this paddle wheel aerator machine was stainless steel, because of its ability to be easily welded, machined, resists oxidation and corrosive attack as it being used inside water and readily available.

Design Requirements

The paddle wheel aerator was designed to meet the following requirements:

(1) Low cost
(2) Use locally-available materials
(3) Ease of fabrication
(4) Portability and ease of assemble / disassembly
(5) Repeatability and ease of operation
(6) Low maintenance requirements

Design Equations and Assumptions

Coefficient of friction existing between paddle wheel and water surface, k

$K = tan^{-1} [(sinacot\varphi) / 90 - \varphi]$ ..(1) (John, 1995)

$\varphi = a + (\emptyset / 2)$ ..... (2) (John, 1995)

Where:

φ = Angle of splashing of rotate paddle with horizontal

$\emptyset$ = Splashing angle make with horizontal

α = Angle of splashing resistance of rotate paddle with depth

The calculation for the Vertical Water force per unit depth (PV)

$PV = \gamma Z^2 N_\gamma + CZN_c + C_aZN_a + gZN_g$ ..... (3) (John, 1995)

The sideways water force per unit width PS

$PS = [(C_aZN_{SC} / 2) + N_{sa} + (N_g / \gamma)^2 N_{sa}] k$ ..... (4) (John, 1995)

Where:

Nr, Nc, Ng and *Nα* are dimensionless (Resce factors)

Y = Water unit weight (N/m^2)

Z = Depth of blade (m)

The value for the resistance force P

$P = P_s + P_v cos\beta$ ..... (5) (John, 1995)

Where: β = Angle of water / interface between paddle edge and water

The draught per unit width D_F

$D_F = PVsin (a + \beta) + PSsina + C_a\gamma cosa$ ..... (6) (John, 1995)

The Vertical Force per Unit Width F_V

$F_V = PVcos (a + \beta) + PScosa + C_aN$ ..... (7) (John, 1995)

The total vertical force per unit width V_T

$V_T = F_V.b$ ..... (8) (John, 1995)

Bending moment for the machine M

$M = 2 / 3 V_T cosa \times h$ ..... (9) (John, 1995)

$\delta_x = Ml / I$ ..... (10) (Khurmi and Gupta, 2011)

$ba = b \times factor\ of\ safety$ .....(11) (John, 1995)

The total power requirement to rotate the paddle wheel

$P = P_r b2\pi rn$ ..... (12) (John, 1995)

Selection of the dimension of spur gear and pinion and determination of shaft diameter

Gear and pinion were selected and determination of shaft diameters for both electric motor and paddlewheel using Khurmi and Gupta, 2011 equations

Aeration Test

The aerator performance was conducted using Non-steady-state aeration test. The test basin was filled to the appropriate depth with water from a tap. Enough Cobalt Chloride

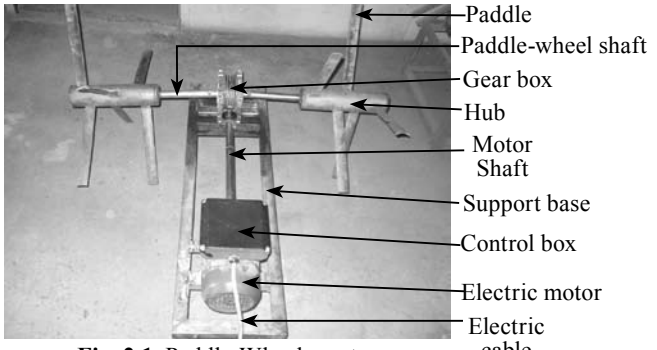

Fig. 2.1 Paddle-Wheel aerator

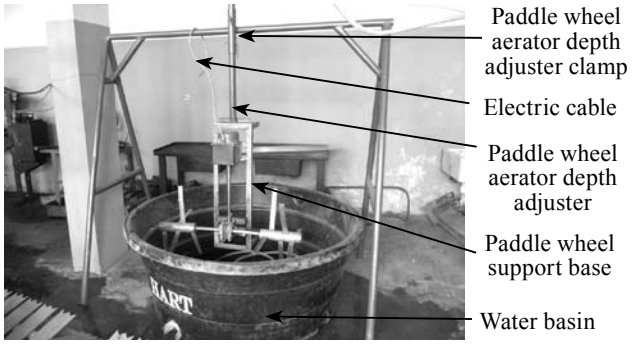

Fig. 2.2 Mounted Paddle Wheel Aerator for Operation

and Sodium Sulphite were provided in the test basin and mixed by running the aerator. The masses of Cobalt Chloride and Sodium Sulphite used per cubic metres are presented in **Table 2**. The aerator shaft was 105 cm above the floor of the aerator test basin (**Fig. 2.1**). Oxygen-transfer tests were conducted in basin. After maintain DO between 0.0 -0.1 mg .L for about 5 minutes, the paddle wheel aerator was run and dissolved oxygen (C_m) was taken at two minutes interval until DO increased from 0% saturation to at least 90% saturation. This prototype paddle wheel aerator operation performance was powered throughout by 0.75 kW (1 hp) electric motor at 881 rpm at various depth range from 16 cm to 30 cm and volume range of 1 m^3 to 8 m^3. At 1 m^3 interval, the optimum uniformity effectiveness of the machine was determined in transmitting dissolved oxygen in the water over two minutes interval. The DO concentrations at saturation (C_s) for water in the aerator test basin were computed for the ambient water temperature and barometric pressure at 15 cm depth with the initial dissolved oxygen (C_s) 6.65 mg/l and water temperature at 28.8°C and barometric pressure at 758.8 mm Hg using a polarographic DO meter, thermometer and aneroid barometer respectively. A polarographic DO meter was used to measure DO concentrations (DO_m) at three places in the basin for at ten equal time intervals while the aerator raised the DO concentration from less than 10% of saturation to about 90% of saturation. The mass oxygen-transfer coefficient at the test temperature (K_La) was calculated as the slope of the regression line for the natural logarithm of the DO deficit (C_s - C_m) relative to time between 10% and 70% saturation. The K_La was determined for each sampling point. The K_La was corrected to 20°C by

$$(K_La)_{20} = K_La \times 1.024^{20-T} \quad \text{..... (13)}$$

The standard oxygen transfer rate (SOTR) and the standard aeration efficiency (SAE) were used to determined the aerator performance:

$$SORT = K_LaT(kO_2)\ /m^3(1 \times 10^{-3}\ kg/g) \quad \text{..... (14)}$$

$$SAE = SORT / P \quad \text{..... (15)}$$

Where:

K_La = Oxygen transfer coefficient

T = Temperature (°C)

P = Power (kW)

Results and Discussion

Prototype of paddle wheel aerator is presented in **Fig.s 2.1** and **2.2**. The predictive equations indicated that the oxygen transfer rate (OTR), standard oxygen transfer rate (SOTR) and standard aerator efficiency (SAE) were found to decrease with increase in the volume of water. The result agreed with Boyd (1998) that the standard oxygen transfer rate (SOTR) and standard aerator efficiency (SAE) of the paddle wheel aerators were inversely proportional to the volume of water, other parameters remain constant. The summary of the results of the developed aerator is presented in **Table 3**. This finding differs slightly from evaluations made by other investigators. Result of Boyd (1990) evaluates indicated that standard oxygen transfer rate and standard aerator efficiency for twenty four types of the paddle wheel aerators ranged from 1.9-8.5 (kg O^2 hr^{-1}) and 1.2-5.2 (kg O^2 kW^{-1} hr^{-1}) respectively. Evaluation of Ahmad and Boyd (1997) and Moore and Boyd, (1992) indicated that standard oxygen transfer rate and standard aerator efficiency for six paddle wheel aerators ranged from 5.2-18.5 (kg O^2 hr^{-1}) and 2.6-3.0 (kg O^2 kW^{-1} hr^{-1}) respectively. These differences may be due to different size of paddle, numbers of paddle, arrangement of the paddle on the hub, speed of the paddle wheel aerator, the depth of operation, types of prime mover, power used, geometrical of basin and physicochemical properties of water. The effectiveness level, the range and restrictive feature was presented in **Table 4**. The results indicated that the effectiveness of the designed prototype machine depends on the volume of water and it is occurred at 2 m^3 or less volume of water, the prototype machine developed provided adequate supply and uniform and equal distribution and mixing of dissolved oxygen in the system (see from **Fig. 2.2**) 2 m^3 to 5 m^3 supplied and provide mixing of dissolved oxygen at

Table 2 The quantity of Cobalt Chloride and Sodium Sulphite used per cubic metres for the deoxygenated volume of water

Volume (m^3)	Mass of Cobalt Chloride (g)	Mass of Sodium Sulphite (g)
1	20	2,000
2	40	4,000
3	60	6,000
4	80	8,000
5	100	10,000
6	120	12,000
7	140	14,000
8	160	16,000

Table 3 Summary of Oxygen transfer coefficient, Standard Oxygen Transfer Rate (SOTR) and Standard Aeration Efficiency (SAE) for the Paddle wheel aerator

Volume of Water (m^3)	Gradient	Oxygen transfer coefficient K_La (hr^{-1})	SOT R (kg O^2hr^{-1})	SAE (kgO^2KW^{-1} hr^{-1})
1	0.16	8.19	1.30	1.34
2	0.14	7.20	1.29	1.30
3	0.13	6.65	1.25	1.27
4	0.11	5.56	1.21	1.23
5	0.09	4.65	1.19	1.19
6	0.08	4.18	1.11	1.17
7	0.07	3.52	1.10	1.15
8	0.06	3.08	1.09	1.13

non-uniformity of dissolved oxygen in entire volume. At pond water volume above 5 m^3, dead zones and oxygen stratification occurred. From this result of the developed prototype performance evaluation and analysis, machinery extrapolation design development can be carried out for pond water volume in multiples of 2 m^3 pond water.

Conclusions

A pilot scale, low-cost, portable prototype paddle wheel aerator was developed locally. The machine was operated in circle and there was dissolved oxygen gradient in basin. More engineering and planning are required to use the machine, such as designing the structural supports, baffles and tank walls/bottom. Long delivery time is common. The machine is effective and efficient at water volume equal to or less than 2 m^3 pond water. This device is recommended for modification to optimize its functions and for scaling up for the benefit of the large scale fish industry.

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Table 4 The effectiveness level, range and restrictive feature of the paddle wheel aerator

Effectiveness level	Range (m^3)	Restrictive feature
High	≤ 2	adequate supplied, equal distribution and mixing of dissolved oxygen with the system
Medium	2-5	supplied and provide mixing of dissolved Oxygen at non-uniformity in the system
Low	> 5	Dead zone and oxygen stratification occurred

Determination of Residue, Drift and Biological Efficacy of Different Spray Methods Against Flower Thrips (Frankliniella spp.) (Thys., Thripidae) in Strawberries

by
Yarpuz-Bozdogan, N.
Vocational School of Technical Sciences
University of Cukurova, Adana
TURKEY
nyarpuzbozdogan@cu.edu.tr

Atakan, E.
Dept. of Crop Protection
Faculty of Agriculture
University of Cukurova, Adana
TURKEY

Bozdogan, A. M.
Dept. of Agricultural Machinery
Faculty of Agriculture
University of Cukurova, Adana
TURKEY

Erdem, T.
Dept. of Agricultural Machinery
Faculty of Agriculture
University of Cukurova, Adana
TURKEY

Daglioglu, N.
Dept. of Forensic Medicine
Faculty of Medicine
University of Cukurova, Adana
TURKEY

Kafkas, E
Dept. of Horticulture Faculty of Agriculture
University of Cukurova, Adana
TURKEY

Abstract

The main objective of this study was to determine efficacy of the different spray methods on flower thrips (*Frankliniella* spp.), plant coverage, drift, and residues on strawberries. In this study, three different types of spray nozzles were tested: hollow cone nozzle (M1); air assisted spinning cage nozzle (M2) and flat fan nozzle (M3). Trials were carried out in 2007 and 2008. Pesticide residues were analyzed with Gas Chromatography/Nitrogen Phosphorus Detector (GC/NPD). Strawberries were analyzed based on malathion residues up to 6 days after spraying. The results showed that pesticide residues on strawberries were lower than maximum residue level (MRL) values according to WHO, FAO and EC. The lowest spray drift outside treated field was obtained in M2 in 2007 and 2008. The highest biological efficiency on the thrips was determined in M2 in both years.

Keywords: Pesticide Residue, Drift, Biological Efficacy, Gas Chromatography, Nitrogen Phosphorus Detector (NPD)

Introduction

Flower thrips (*Frankliniella* spp.) are among the harmful insect species in Cukurova Region, destroying the flower and floral organs, turning into brown of petal leaves, bronzing and shape disorders on fruits (Gremo *et al.*, 1997; Steiner, 2003; Steiner and Goodwin, 2005). Thrips hide in flowers and flower buds and protect itself from pesticides. Systematic pesticides cannot be moved until the flowers, the efficiency of such pesticide cannot provide the desired success. Therefore, pesticides are frequently applied against to flower thrips by farmers. Thus, increasing pesticide residues on fruit and environmental pollution occur as a result of more spraying. Application techniques of pesticides and formulation specifications can affect the biological efficacy. In general, the optimum drop diameters are 10-150 μm in pesticide applications (Anonymous, 2003). However, the most important problem during application is drift. Small droplets

drift to non-target due to meteorological factors like wind speed and evaporate (Yarpuz-Bozdogan, 2011). In agriculture, sustainability provides a balance between the ecological environment and environmentally friendly agricultural applications such as tillage, fertilizing, spraying of pesticides, harvesting, etc. (Bozdogan, 2014). For sustainable agriculture, appropriate nozzles should be used in pesticide application for reduce drift (Yarpuz-Bozdogan and Bozdogan, 2009). Effective pest and disease control is accomplished with the help of sprayers that have better designed nozzles (Jain *et al.*, 2006). Strawberry is one of the direct consumption fruits. For this reason, in pesticide application, it is desired to have minimum pesticide residue on strawberry and maximum biological efficacy. In recent years, environmentally application pesticide techniques were developed like air assisted pesticide applications and band spraying. Air assisted pesticide application technique helps to maximum residue in flowers and more penetration into crop canopy (Taylor and Andersen, 1989; Pannetton *et al.*, 1996; Bayat and Yarpuz-Bozdogan, 2005; Dhalin *et al.*, 2008). Band spraying technique provides less pesticide consumption and less pesticides within rows according to conventional application technique (Debear *et al.*, 2005; Landers, 2007). In Turkey, farmers do not have enough knowledge about pesticides application methods against flower thrips in strawberry. The objective of this study was to determine appropriate spray methods against flower thrips (*Frankliniella* spp.) in strawberry for sustainable agriculture.

Material and Methods

In this study, strawberries (Fragerria X ananassa, Duch, Rosaceae) were grown in research experimental fields of Yaltir Corporation in Adana which is in Mediterranean region of Turkey. The effectiveness of different spray methods was studied against Flower Thrips (*Franklinella occidentalis*) on 24 May, 2007 and 22 May, 2008. The spraying experiment was designed as a complete randomized block with four replicates; also 10 plants of cultivar camarosa species were randomly selected in each replicate. Each plot covered 10 m in length and 5.0 m in width. In this study, malathion/Malathion 20 EC™ (190 g l^{-1}) was used for strawberries. Maximum residue level (MRL) value of Malathion was 1 mg/kg (EC, 2000). During the trials, temperature, wind velocity and relative humidity were recorded. These were measured by digital Hotwire Anemometer CE (Lutron™ AM-4204 HA) and digital Humidity/type k Thermometer CE (Lutron™ HT-3006 HA).

All chromatographic analyses were performed on an Agilent (6890 N) gas chromatograph with an autosampler automatic injector, equipped with a nitrogen-phosphorus detector (NPD) and a fused silica capillary column (Agilent 19091J-413, HP-5 5% phenyl methyl siloxane (30 m × 0.32 mm × 0.25 µm)). Liquid-liquid extraction method was used.

Two different types of spray methods were used: (1) broadcast spray method with hollow cone nozzles (HC) (200 l/ha) and air assisted spinning cage nozzles (ASC) (20 l/ha), and (2) band spray method with flat fan nozzles (FF) (200 l/ha). Only one field sprayer was used. The following options were applied onto the field sprayer: (1) Hollow cone (HC) nozzles (M1) (Taral™, D4-45, 50 cm above the crop) as broadcast spraying. (2) Air-assisted spinning cage (ASC) nozzle (M2) (Micron™, fan/atomizer speed 4000 rpm) as broadcast spraying. ASC nozzles were placed towards ground plane with an angle of 45°. (3) Row application kit with flat fan (FF) nozzles (M3) (Arag™, 11001, one directed towards the center and two towards the sides of the crop) as band spraying. The forward speed of the tractor was 6.5 km/h and the power-takeoff (PTO) rotational speed was 540 rpm. The spray boom of the field sprayer (HC) covered 4 rows of the strawberry plantation in one swath. On the other hand, the spray boom (single-sided) of the field sprayer with FF and ASC nozzles covered two rows of the strawberry plantation in one swath.

Strawberries were collected after the first hour (accepting as zero) then first, second, third, fourth, fifth and sixth days after spraying for the residue analysis. They were randomly sampled 300 gm in each plot. The samples were kept in plastic bags. The first order rate equation was fitted to give the best agreement between calculated and observed concentration (**Eq. 1**) (Fogg *et al.*, 2003; Yarpuz-Bozdogan *et al.*, 2011).

$$R = R_0 . e^{-kt} \quad \text{..... (1)}$$

Where: R is the concentration (mg kg^{-1} soil), t is the time (days) and k is the degradation rate ($days^{-1}$).

The drift measurement paper was laid perpendicular to the line of travel of the sprayer and parallel to the wind direction. Using the method described by Rowinski *et al.*, spray drift papers were placed horizontally along the line of measurement at distances of 1, 2, 3, 4, 5, 7.5, 10, 15, 30 and 50 m respectively, from the end of the boom. After spraying, the filter paper samples were collected from field and placed in bottles (height: 9 cm; diameter: 4.5 cm) and taken to laboratory.

Frankliniella spp. to determine the effect of the density of population in each of the plots, the 15 random flowers, in all trials, 60 flowers in total were collected. Three flowers taken from each plot were put in a plastic tube (50 ml) with 60% ethyl alcohol. The biological efficacy of the pesticide used against thrips, could not evaluated during both two

Table 1 Pesticide residues on strawberries following pesticide application (Mean values ± SD of four replicates)

Year	Spray Methods	Active Ingredient (mg/kg) (Days after treatment)						
		Day						
		0*	1	2	3	4	5	6
2007	M1	0.1007±0.027	0.0192±0.007	0.0131±0.008	0.0118±0.005	0.0092±0.003	0.0069±0.003	0.0052±0.004
	M2	0.0065±0.010	0.0034±0.002	0.0020±0.001	0.0017±0.001	0.0012±0.001	0.0011±0.001	0.0009±0.001
	M3	0.0447±0.018	0.0203±0.013	0.0119±0.016	0.0107±0.003	0.0059±0.005	0.0041±0.002	0.0035±0.002
	UC**	0.0067±0.003	0.0068±0.007	0.0082±0.007	0.0018±0.001	0.0026±0.003	0.0009±0.001	0.0004±0.001
2008	M1	0.0236±0.002	0.0102±0.001	0.0056±0.001	0.0047±0.001	0.0033±0.001	0.0029±0.014	0.0014±0.001
	M2	0.0068±0.001	0.0054±0.001	0.0047±0.001	0.0040±0.001	0.0030±0.001	0.0022±0.001	0.0002±0.001
	M3	0.0165±0.009	0.0096±0.001	0.0070±0.001	0.0046±0.001	0.0030±0.001	0.0025±0.001	0.0005±0.001
	UC**	0.0013±0.002	0.0011±0.002	0.0008±0.001	0.0003±0.001	0.0003±0.001	0.0000±0.000	0.0000±0.000

* The first day of pesticide application

** UC: Untreated Control

years because it is below 20%.

According to results of a randomized block design, analyzes were conducted using SPSS statistical package program, and the average residue levels of pesticides in Duncan's multiple comparison test ($P < 0.05$) are discussed. To determine whether the effect of population density of thrips, the analysis of variance (ANOVA) was conducted to the numerical values and the differences between the mean values were investigated to $P < 0.05$ level of significance according to Duncan's multiple comparison test.

Results and Discussion

Pesticide residues on strawberry in 2007 and 2008 are shown in **Table 1**.

According to **Table 1**, the highest residues were obtained on the first day (day 0), and the lowest residues were obtained on the sixth day. The highest residues were obtained in M1 and the lowest residues were obtained in M2 in 2007 and 2008. Pesticide residue value of first day was 95% on sixth day in 2007 with M1 and in 2008 pesticide residues was decreased to 94%. Average pesticide residues (mg/kg) on strawberries of Malathion applied through different spray methods are shown in **Table 2**.

According to **Table 2**, when the spray methods are compared, the highest pesticide residues were obtained in M1 in 2007 and 2008. In statistical analysis, pesticide residues in M1 were significantly different from the other spray methods. When spray methods are compared in statistical analysis, the lowest pesticide residues were obtained in M2 in 2007 and 2008.

Parameters for pesticide decline of strawberries are shown in **Table 3**.

The equations were used for other parameters such as Kdec, R0, Rp, etc. These parameters led to determination of the consuming day of

Table 2 Average pesticide residues on strawberries

Spray Methods	Average pesticide residues (mg/kg)*	
	Mean ± SD	
	2007	2008
M1	0.0237±0.033 c	0.0084±0.008 d
M2	0.0024±0.004 a	0.0038±0.002 b
M3	0.0145±0.016 b	0.0062±0.006 c
Untreated control	0.0039±0.004 a	0.0005±0.001 a

* Means with the same letter are not significiantly different at the 5% level of least significant difference.

Table 3 Parameters for pesticide decline of strawberries

Spray Methods	Equation	R^2	K_{dec} ($days^{-1}$)	R_0 (mg/kg)	R_6 (mg/kg)	Suggested consuming day after pesticide application according to MRL (FAO, 2006; WHO, 2006; EC, 2000)
2007						
M1	$CA = 0.0696 . e^{-0.4032t}$	0.8	0.4032	0.0696	0.0062	CAo < MRL
M2	$CA = 0.0066 . e^{-0.3107t}$	0.92	0.3107	0.0066	0.001	CAo < MRL
M3	$CA = 0.0519 . e^{-0.4122t}$	0.96	0.4122	0.0519	0.0043	CAo < MRL
2008						
M1	$CA = 0.0262 . e^{-0.4114t}$	0.94	0.4114	0.0262	0.0022	CAo < MRL
M2	$CA = 0.0165 . e^{-0.4580t}$	0.68	0.458	0.0165	0.0011	CAo < MRL
M3	$CA = 0.0303 . e^{-0.5010t}$	0.9	0.501	0.0303	0.0015	CAo < MRL

R = Residue (mg/kg); t: Time (day); R^2 = Coefficient of determination; K_{dec}: Decline constant ($days^{-1}$); R_0 = Initial residue (mg/kg); R_6 = Residues at pre-harvest interval of pure a.i. (mg/kg)

Table 4 Horizontal Spray drift

Year	Spray Methods	Spray deposit (mg/cm²)				
		Distances from the sprayer (m)				
		1 m	2 m	3 m	4 m	5 m
2007	M1	2.047	1.059	0.028	0.027	0.027
	M2	0.027	0.022	0	0	0
	M3	0.057	0.051	0.044	0.043	0.037
2008	M1	4.908	3.756	0.579	0.454	0.287
	M2	0.328	0.29	0.271	0.246	0.197
	M3	1.163	0.987	0.445	0.303	0.192

Table 5 Efficacy of three different spray methods on *Frankliniella* spp. population density in 2007

Spray Methods[b]	Precount (24/05)	After spraying (day, date)[a]			
		3. day (27/05)	7. day (30/05)	12. day (4/06)	20. day (12/06)
M1	19.6 a	13.3 b	15.6 a	12.9 a	17.5 a
M2	19.2 a	9.4 c	12.4 b	10.4 b	16.0 a
M3	20.3 a	13.9 b	15.0 a	14.0 a	9.7 c
Control	21.1 a	17.7 a	14.5 ba	12.9 a	11.6 b

[a] means in the same column followed by the same letter do not differ significantly (P < 0.01) by DUNCAN test
[b] Trial was carried out on 24 May

strawberries following pesticide application. The MRL of Malathion was 1 mg / kg according to EC, WHO and FAO.

In this study, when the recommended rate of Malathion was applied, the residue levels were decreased 93% of M1, 99% of M2, and 94% of M3, than MRL levels in 2007 and were decreased 97% of M1, 98% of M2, and 97% of M3 in 2008. In this study, the residues on strawberries were below the legal limits (MRL) value. Therefore, in 2007 and 2008 for each spray method, the recommended strawberry fruit consumption was concluded approximately 1 day after spraying. Kara *et al.* (2002) suggested that it must take care of time interval between last pesticide application and harvest time. Juraske *et al.* (2012) showed that pesticide residues in passion fruits measured at recommended harvest dates were all below maximum residue level (MRL). Stensvand and Christiansen (2000) reported that the recommended dose of fungicide (tolylfluanid) was applied against the strawberries which were grown in the greenhouse. One week later after the spraying, the pesticide residues were three times higher than MRL value. However, after two weeks later the amount of pesticide residue was found below MRL value. Safi *et al.* (2002) observed that pesticide residues on cucumber, tomato, and strawberry after pesticide application were below MRL. Yarpuz-Bozdogan *et al.* (2011) indicated that pesticide residues on strawberries for broadcast and band spraying were below the suggested MRL of dicofol by Commission Directive 2000/42/EC.

Spray drift at different nozzles are shown in **Table 4**.

The highest spray drift was obtained with M1 in all nozzles both in 2007 and 2008. Coarse droplets produce less drift than fine droplets (Taylor and Andersen, 1989; PISC, 2002). The highest amounts of pesticide residues were obtained at 1 meter in all nozzles. The lowest spray drift was obtained with M2 in all nozzles both in 2007 and 2008. Some researchers indicated that spray drift can be reduced by air-assisted technology (Pannetton *et al.*, 1996; Holownicki *et al.*, 2000; Piche *et al.*, 2000; Yarpuz-Bozdogan, 2005; Bozdogan and Yarpuz-Bozdogan, 2008; Yarpuz-Bozdogan and Bozdogan, 2009; Sayinci and Bastaban 2011; Yarpuz-Bozdogan *et al.*, 2011).

The **Table 5** shows the summarized efficacy of three different spray methods on *Frankliniella* spp. population density in 2007. As seen in **Table 5**, mean numbers of thrips was reduced in all plots at sampling dates after pre-count. The thrips population even after one day from spray was not affected by Malathion. Mean numbers of thrips at third day after spraying was similar to M1 and M3, and significantly high in M2. Mean numbers of thrips at 7th and 12th days after spraying was similar to M1, M3 and control plots, and was low in M2. Numbers of thrips in M1 and M2 was significantly higher than M3 and control plots. The lowest number of thrips was obtained in M3. This situation may be the difference in the number of flowers. The effect of three different spraying methods on *Frankliniella* spp. population in 2008 is given in **Table 6**.

The number of thrips increased in all plots after spraying. Malathion may not have biological affected on thrips. Although the biological efficiency was low, efficiency of different spraying methods on thrips population were significantly differ-

Table 6 Efficacy of three different spray methods on *Frankliniella* spp. population density in 2008

Spray Methods[b]	Precount (20/05)	After Spraying (day, date)[a]				
		3. day (24/05)	6. day (27/05)	10. day (31/05)	14. day (04/06)	21. day (11/06)
M1	34.7a	69.5b	82.5a	66.8a	38.0a	19.8b
M2	30.0a	53.8c	58.0b	57.5b	36.0a	28.7a
M3	30.0a	57.3c	69.6c	76.1a	31.1a	32.0a
Control	34.1a	86.2a	79.2a	79.7a	34.5a	18.8b

[a] means in the same column followed by the same letter do not differ significantly (P < 0.05) by DUNCAN test.
[b] Trial was carried out on 22 May

ent from the third day. The number of thrips was similar in M2 and M3, and high in M1 at the third day after spraying. Differences among spraying methods were observed at the sixth day. The lowest number of thrips was obtained in M2 at the tenth day. After the tenth day, there was no observed efficiency of different spray methods on thrips population. The biological efficacy of Malathion on thrips was very low in both years. It was indicated that *F. occidentalis* resistance to pesticides in strawberries (Immaraju *et al*., 1992; Robb *et al*., 1995). In this study, mean numbers of thrips in M2 was statistically significant lower than M1 and M3.

Conclusions

In this study, pesticide residues on strawberries in all spray methods were below the legal limits (MRL) according to WHO, FAO and EC. The lowest spray drift outside treated field was obtained in M2 in 2007 and 2008. The highest biological efficiency on the thrips was determined in M2 in both years. In this study, it was concluded that the best result was obtained with M2 in all spray methods.

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Determination of Dermal Exposure of Operator in Greenhouse Spraying

by
Nigar Yarpuz-Bozdogan
Vocational School of Technical Sciences
University of Çukurova, Adana
TURKEY
nyarpuzbozdogan@cu.edu.tr

Ali Musa Bozdogan
Department of Agricultural Machinery
Faculty of Agriculture
University of Çukurova, Adana
TURKEY

Nebile Daglioglu
Department of Forensic Medicine
Faculty of Medicine
University of Çukurova, Adana
TURKEY

Tunahan Erdem
Department of Agricultural Machinery
Faculty of Agriculture
University of Çukurova, Adana
TURKEY

Abstract

The objective of this study was to determine of dermal operator exposure by patch method of fungicide sprayed in tomato greenhouse. In this study, the patch method was used for determining of dermal pesticide contamination on operator in greenhouse spraying. The patches (shoulder, back, chest, upper and lower arms, thigh, lower legs, foot, ankle, hands, and mask) each measuring 10 × 10 cm^2, were attached to operator. The operator sprayed distances of 200 m in greenhouse. Each trial was replicated three times. After the trials, all patches were collected and were analyzed in the laboratory. In laboratory, all chromatographic analysis was performed on gas chromatograph equipped with electron capture detector (GC-ECD). From the results of this study, the highest pesticide residues were obtained on the left hand, foot and ankle. In addition, pesticide residues on operator's lower parts of the body were 9.205% higher than operator's upper parts of the body. The total recovery on lower and upper body were 52.197 (%) and 47.8 (%). It was concluded that operators should wear gloves and footwear for minimizing pesticide exposure when pesticide is applied with standard spray gun.

Keywords: Greenhouse, Operator Exposure, Pesticide Contamination, Patch Methods, Spray gun

Introduction

The total area of greenhouses in Turkey is approximately 49,741 ha according to data of 2006 (TUIK, 2006). Number of pesticide application in greenhouse is higher than pesticide application in field. Pesticides are defined as any substances used to control pests. The broad aim of pesticide application is to maximize control of the pest with use of minimum amount of pesticide (Senthilkumar and Kumar, 2007). Pesticides can improve quality and quantity of agricultural crops; however, they cause serious environmental and public health problems (Anonymous, 2007; Dahab and Eltahir, 2010). Aschengrau *et al.*, (1996), studied on brain cancer rates in people living near cranberry agricultural fields in Cape Cod, Massachusetts. Results showed that living within 793 m of cranberry growing area resulted in twice the risk for all brain cancers and nearly a 7-fold increased risk for a type of brain cancers known as astrocytoma (Aschengrau *et al.*, 1996). In 2004, 3 million people suffered from pesticide poisoning (Pimental, 1992). Dermal exposure to pesticides is highly correlated with the manual contact with pesticides treated plants and it is believed to be the major route of pesticide absorption during occupational use (Jurewicz *et al.*, 2009). According to the Council Directive 91/414/EC, human pesticide exposure is investigated considering the operator, the worker,

and the bystander. Operators are persons who mix, load and apply the pesticide (Garreyn *et al*., 2003; Matthews, 2000). Operator exposure is defined as any people who are primarily involved in pesticide application. Operators may be exposed to pesticides through the product landing on the skin, by inhalation or by accidental oral ingestion (Chester, 1993). Operator exposure can be considerably reduced by using personnel protection equipment (PPE) (Chester, 1993; Tuomainen et al., 2002; Nuyttens, *et al*., 2004; RCEP, 2005). In Turkey, generally, operator and worker do not use PPE. Bozdogan and Yarpuz-Bozdogan (2009), calculated that wearing protective clothes reduced the potential risk for worker from 1.000 to 0.637 in defoliant application. The area of exposed skin is minimized by using of PPE such as rubber gloves, boots, and apron (Nilsson, 1998; Matthews, 2006; Hamey, 2001; Claman, 2004; Bozdogan and Yarpuz-Bozdogan, 2008; Yarpuz-Bozdogan and Bozdogan, 2009; Bozdogan, 2014). Claman (2004) indicated that operators need to be warned with simple clear labelling to minimize exposure to toxins by use of protective clothing, gloves and careful application techniques during pesticide application. Use of PPE is very important to reduce dermal exposure to pesticides. Suitable protective clothing and respiratory protection are needed during pesticide application in the greenhouses (Tuomainen *et al*., 2002). The potential dermal exposure to pesticide sprays can be measured with the patch method or with whole body dosimetry method (Machera *et al*., 2003). The patch method involves the use of a number of absorbent patches (gauze, cellulose paper, cotton fabric, etc.) of a defined size attached to different parts of the body (Nuyttens *et al*., 2004; Machera *et al*., 2003).

The objective of this study was to determine of dermal operator exposure with patch method of fungicide sprayed in greenhouse. This study was the first one concerning dermal operator exposure to fungicide in greenhouse in Turkey.

Materials and Methods

Field Trials

The trials were carried out in a greenhouse in the Adana province of the Mediterranean Region of Turkey on June 23, 2011. One greenhouse (200 m^2) growing tomatoes were selected for determination of operator exposure. Tomatoes were planted one rows and the inner row distance was 90 cm. The height of the crops was approximately 32 cm.

Pesticide

The active ingredient of the pesticide used in this research was mancozeb. Mancozeb is used to protect many fruit, vegetable, nut and field crops against a wide spectrum of fungal diseases, including potato blight, leaf spot, scab (on apples and pears), and rust (on roses). It is also used for seed treatment of cotton, potatoes, corn, sorghum, peanuts, tomatoes, flax, and cereal grains. Mancozeb is available as dusts, liquids, water dispersible granules, as wettable powders, and as ready-to-use formulations. It may be commonly found in combination with zineb and maneb (EXTOXNET, 1996). In this study, the dosage of mancozeb was 200 gram active ingredient/100 litres.

Spraying Equipment

Standard spray gun was used in this research. The standard spray gun is the most common spray equipment in the Adana province of the Mediterranean Region of Turkey. The operator walking speed was 4.5 km per hour. The spray pressure was 20 bar and the average flow rate was 10.2 litre per minute.

Sampling Method and Analysis

The dermal exposure of operator was measured using the patch method (Nuyttens *et al*., 2004). Eleven patches (shoulder, back, chest, upper and lower arms, thigh, lower legs, foot, ankle, hands and mask), each measuring 10 × 10 cm^2, were attached to operator's coverall using pins. The operator wore a pair of latex gloves and the patches (10 × 10 cm^2) were attached on the latex gloves. Cotton fabric was used as patches. After the spraying with standard spray gun, the patches were collected and were placed in glass containers (500 ml) and brought from greenhouse to laboratory. In laboratory, they were extracted using 150 ml volumes of methanol. The containers were shaken for 30 minutes in a water bath with a shaker at room temperature. A 1.7 ml fraction of each extract was sealed in a gas chromatograph vial and analyzed.

Estimation of Dermal Deposition

Dermal deposition of operator was measured using Eq. 1 (Dubelman *et al*., 1982; Bozdogan and Yarpuz-Bozdogan, 2008). In this study, the total operator exposure due to dermal deposition for an operator weighing 70 kg.

$$Dermal\ Deposition\ (\mu g/kg) = [(Measured\ \mu g / cm^2 \times Exposed\ area\ (cm^2)) / (70\ kg\ of\ body\ weight)] \quad \text{Eq.1}$$

where, measured $\mu g\ cm^{-2}$ is the total value given for residue and exposed are is surface area of operator on the average of values for the operator's body parts (**Table 1**).

Meteorological Conditions

During the trial, the temperature and the relative humidity in the greenhouse were recorded. They were measured by digital Humidity/type k Thermometer CE (Lutron™ HT-3006 HA). The relative humidity and temperature in greenhouse ranged from 67 to 70% and from 39.8 to 46°C, respectively.

Instrumentation and Chromatographic Conditions

All chromatographic analysis was performed on a Perkin Elmer Company™ Autosystem XL gas chromatograph equipped with electron capture detector (GC-ECD).

The GC-ECD operating conditions were as follows. Oven initial temperature 50°C, initial time 2.2 min, equilibration time 2.00 min. Initial temperature 250°C, detector temperature 300°C and gas flow 1 ml/min and gas type helium.

The analytical procedure was applied according to GC methods (Pesticide Analytical Manual, 1999).

Statistical Analysis

SPSS 14.0 for Windows (SPSS, Chicago, IL, USA) was used for statistical analysis. Comparisons of the mean pesticide residues were quantified by the one-way analysis of variance (ANOVA) at $P < 0.05$.

Results and Discussion

Mancozeb is widely used in agriculture due to its low acute toxicity and short environmental persistence, the total amount of mancozeb used is increasing worldwide (Colosio *et al.*, 2002). The average pesticide residues (ng cm^{-2}) of Mancozeb on each body part are presented in **Table 1**.

As seen in **Table 1**, the highest average pesticide residues were obtained on the left hand (21.948±1.202 ng cm^{-2}), left (17.489±0.811 ng cm^{-2}) and right (13.872±1.587 ng cm^{-2}) ankle and left thigh (12.623±0.774 ng cm^{-2}). The operator used the spray gun and sprayed the pesticide to the tomatoes in the greenhouse. The operator was right-handed. There was difference between the left hand and right hand because of a large spray cloud close to the left hand. The exposure of the left hand was higher than that of the other parts of the body (**Table 1**). Tuomainen *et al.* (2002) showed that during pesticide mixing and loading in the greenhouses over 99% of the potential dermal exposure was accounted for by the workers' hands. Machera *et al.* (2003) obtained the similar results in greenhouse spraying. Nuyttens *et al.* (2004) indicated that the highest exposure of the hands was measured with the spray lance for the left as well as the right hand. Bjugstad and Hermansen (2009) reported that the potential operator exposure was significantly higher for a tunnel system compared with the open field system for strawberry and raspberry.

The total recovery (%) on operator according to upper (mask, shoulder, chest, back, upper and lower arm and, hands) and lower (thigh, lower leg, ankle and foot) body are shown in **Fig. 1**.

As seen in **Fig. 1**, the total recovery (%) found on lower body parts was higher than the total residues (%) on upper body parts. The total recovery on lower and upper body were 52.197 (%) and 47.8 (%). Tuomainen *et al.* (2002) showed that during the application period in greenhouse lower (60%) and upper (21%) were the body parts,

Table 1 Average pesticide residues (ng cm^{-2}) found in each one of the body part (Mean values±SD of four replicates)

Body Part		Mean values±SD (ng cm^{-2})	Total Recovery (%)
Mask		1.998±0.188	1.173
Chest		3.573±0.363	2.097
Back		4.212±0.797	2.472
Shoulder	Right	5.195±0.734	3.049
	Left	7.503±0.620	4.403
Upperarm	Right	7.047±0.471	4.136
	Left	7.523±0.237	4.415
Lowerarm	Right	8.805±0.665	5.167
	Left	7.766±0.139	4.558
Thigh	Right	8.116±0.905	4.763
	Left	12.623±0.774	7.408
Lower leg	Right	9.399±0.998	5.516
	Left	8.972±0.442	5.265
Ankle	Right	13.872±1.587	8.141
	Left	17.489±0.811	10.264
Foot	Right	8.105±1.305	4.756
	Left	10.369±1.282	6.085
Hand	Right	5.877±0.215	3.449
	Left	21.948±1.202	12.88
Total Pesticide Residues		170.392	˜100

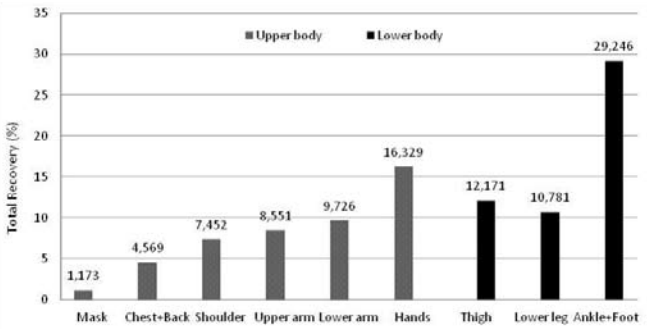

Fig. 1 Total recovery (%) on operator according to upper and lower body

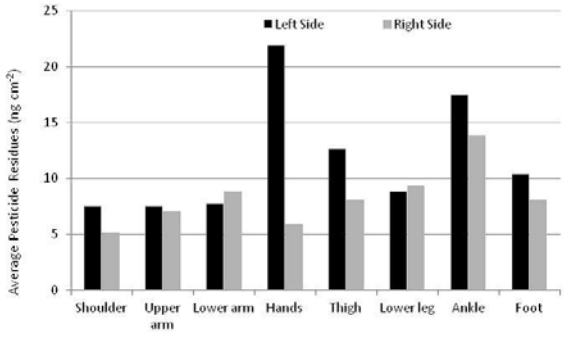

Fig. 2 The average pesticide residues (ng cm^{-2}) on operator according to right and left side

which were mostly contaminated. The highest total recovery (%) on lower and upper body was obtained in foot+ankle and, hands, respectively. The total recovery (%) on the foot+ankle was about 29.246% of the total recovery in lower body. The total recovery on the hands was about 16.329% of the total recovery in upper body. The measured exposures of the feet+ankle were the highest of the lower body because the feet and the ankle come into contact with the falling droplets. Stamper *et al.* (1988) reported that legs are the most exposed areas of greenhouse applicators, with 75% of the total dermal exposure. Similarly, Stamper *et al.* (1989) indicated that exposure to outside pads was primarily (84%) to the legs of the applicators in greenhouse. Nuyttens *et al.* (2004) obtained similar results in their greenhouse spraying studies. Nuyttens *et al.* (2004) indicated that the feet were the highest of the entire body because of the falling droplets and the spray cloud in greenhouse. Yarpuz-Bozdogan *et al.* (2000) showed that the highest pesticide residues in greenhouse were found on operator's knee and ankle in knapsack sprayer application. According to Nuyttens *et al.* (2008) the lower the position on the body, the higher is exposure in greenhouse spraying.

The average pesticide residues on operator according to right and left side are shown in **Fig. 2**.

As seen in **Fig. 2**, there was difference between the left and the right hand. The highest pesticide residues were obtained in the left hand. The main reason of this difference is the fact that the operator sprayed with right hand and the left hand moved so large spray cloud close to the left hand. On the other hand, the exposure of the ankle+foot was higher than that of the other parts of the body. Because, sprayed droplets fall to the ground with the effect of the force of gravity and the foot and the ankle come into contact with the falling droplets. Vidal *et al.* (2002) indicated that the highest exposure to pesticides during applications in greenhouses occurs on lower legs and front thighs of the applicators. Nuyttens *et al.* (2008) indicated that the exposure on the right side of the body with the spray gun was about four times smaller than on the left side of the body in greenhouse spraying. Nuyttens *et al.* (2008) reported that depending on the side of the row that was sprayed with lance or gun, there was a difference in exposure between the left and the right side of the body. Cerruto *et al.* (2009) found that the greatest exposure in greenhouse occurs on legs. Because the foliage to be sprayed barely rose above ground level.

The total operator dermal deposition was 2.677 μg kg^{-1} by using Eq. 1. This value can be decreased when the operators use PPE in greenhouse. Yarpuz-Bozdogan (2009) indicated that using of PPE during pesticide spraying should be taken in to account for protecting of human health.

Conclusions

This study was the first one concerning dermal operator exposure to fungicide in greenhouse, in Turkey. In this study, patch method was used to determine dermal deposition of operator in greenhouse. Generally, the operators do not wear any special clothes and personnel protective equipment (PPE) (coveralls, protective suits, footwear, gloves, aprons, respirators, eyewear and headwear) when they spray pesticide to crops in Turkey. However, pesticide residues negatively affect the human health. In this study, the highest pesticide residues were obtained on the left hand. The average pesticide residues found on lower body parts (thigh, lower leg, ankle and foot) was higher than the average pesticide residues on upper body parts (mask, shoulder, chest, back, upper and lower arm and, hands). The measured exposures of the foot+ankle were the highest of the lower body because the foot and the ankle come into contact with the falling droplets. Exposure of pesticide operators can be controlled by use of PPE in greenhouse. Any time operators are using pesticides, they should wear at least a long sleeved shirt and long legged pants, or coveralls. Suitable PPE are needed during pesticide application in greenhouse. The operator exposure can be reduced by wearing personnel protective equipment (PPE).

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■■

New Co-operating Editors

AYUB N. GITAU

Date of Birth: 20 October 1966
Nationality: Kenyan
Present Position:
Chairman and Associate Professor, Department of Environmental and Biosystems Engineering, University of Nairobi
Education Background:
2001-2004: PhD Studies at the University of Nairobi; Obtained PhD degree (2005) in Agricultural Engineering (Soil Mechanical Behaviour, Tillage Modeling and Tool Design Option).
1992-1994: MSc. Studies at the University of Nairobi; Obtained MSc. Degree (1996) in Agricultural Engineering (Power, Machinery and Mechanization Engineering Option).
1987-1990:BSc. Studies at Egerton University; Obtained an Upper Second Class Honours degree in Agricultural Engineering (1990).
Professional Experience:
2015-date: Adjunct Professor, Kenyatta University
2014-date: Associate Professor, researcher, consultant and chairman
2008-2014: Senior Lecturer, researcher and chairman (2011) Department of Environmental and Biosystems Engineering University of Nairobi.
2002-2008: Lecturer and researcher. Department of Environmental and Biosystems Engineering University of Nairobi.
1995-2001: Part-time lecturer. University of Nairobi and JKUAT.
2001-2002: Lecturer and Ag. Head of Department of Agriculture and Natural Resources, Kenya Methodist University. Meru
1995-2000: Lecturer and Engineer: Head of Department of Science and Technology, Kenya Industrial Training Institute (KITI), Ministry of Trade and Industry. Nakuru
E-mail address: ayub.gitau@uonbi.ac.ke; gitauan@yahoo.co.uk

Regional Distribution of the World's Tractor Stock

by
Jan Pawlak
Institute of Technology and Life Sciences
Warsaw Branch
Department of Economic and Energy Analyses
Rakowiecka Str. 32, 02-532 Warsaw
POLAND
j.pawlak@itep.edu.pl

Abstract

The analysis of distribution of tractors in agriculture of 9 regions of the world during 2000-2010 has been carried out. The number of tractors in use at the world's scale in 2000 amounted to 28,509 thousand units. World fleet of tractors in 2010, estimated using an especially elaborated method, increased to 33,333 thousand, or by 17%. The increase was noted in 6 regions; the highest one in the Eastern and Southern Asia (by 114%). The lowest number of tractors per 100 ha of agricultural area, both in 2000 and 2010 was in Sub-Saharan Africa.

Introduction

According to the population growth forecast, the world population of humans will reach 9 billion in 2040 and will probably continue to grow. This means that a global food production capable of feeding such high number of people must grow proportionally. Huge differences in level of both agricultural production and farm mechanization between industrialized and developing countries were shown in the paper presented during the Club of Bologna members meeting in 2002 (Pawlak *et al.*, 2002). Developing countries depend highly on agriculture, and their increase in agriculture productivity without appropriate farm mechanization will not be feasible (Snobar, 2013). The implementation of machinery for agriculture in such countries should increase gross agricultural production (Kic and Zewdie, 2013; Lantin, 2013), promote the efficiency of labor (Sakai, 2013) and contribute towards enhance yields and quality of farming products (Hay, 2013). Therefore, it is necessary to continue analyses concerning the development of agricultural mechanization in different regions of the world as well as finding its effect on productivity of land and labor. As a base of such analyses the appropriate input data is necessary.

Numbers of tractors used in agriculture of different countries as related to agricultural area and to number of farms are indicators of the level of mechanization in particular countries or regions of the world. The serious problem for researcher is decreasing availability of relevant statistical data. In 2000 Faostat published the tractor data for 130 countries, in 2005 for 92, and for 2009 − only for 11. Under such situation the development of method enabling estimation of tractor resources in different regions of the world has been necessary. This has been one of purposes of this paper. The main purpose has been the estimation of number of tractors in 9 regions of the world and their changes during the period of 2000-2010.

GROUP	REGION
I	Industrialized countries with an average farm sizes over 100 ha of agricultural area
II	Industrialized countries based on small farms
(IIa)	Japan
(IIb)	Western Europe and Israel
III	Central and Eastern Europe
IV	Russian Federation (Eurasian country)
V	Former Asian Soviet Republics
VI	South and East Asia and Pacific islands
VII	Middle East and North Africa
VIII	Sub-Saharan Africa
IX	Latin America and Caribbean

Material and Methods

The method for estimating numbers of tractors in 2005 and 2010 has been elaborated. At first, the countries for which the number of tractors in 2005 and 2010 were known or could be calculated were

selected. The data were taken from Faostat as well as from publications of World Bank, Farm Machinery Industrial Research Corporation, VDMA and statistics of particular countries. Apart from the direct data showing number of tractors, calculations have been made, based on World Bank's indexes of units per 100 km^2 of arable land and the area of the arable land in particular countries.

Analysis of the various aspects of the situations of the world's agricultural tractor stock in different areas has been carried out, based on a subdivision of the various nations into 9 main groups (regions), as follows (see page 40):

Adoption of the same subdivision as in the paper of the Club of Bologna enables a comparison between the present study and earlier results and to show trends in the first decade of 21th century.

Basing on data received in this way for countries representing particular groups, totals for each of them have been calculated. The same countries data for 2000, 2005 and 2010 were used. Besides, for 2000 the totals of data available for that year have been summarized for particular groups.

Then, the index showing the share (in 2000) of tractors in use in countries with data available during all period of the study (2000-2010) in total number of tractors of particular group has been calculated using the formula:

$St = TNt / RNt$

where: St − the index showing the share (in 2000) of tractors in use in countries with data available during all period of the study in total number of tractors within particular group;

TNt − total number of tractors in the group in 2000 [units];

RNt − tractors (in 2000) in countries with data available during all period of the study [units].

Assuming that the above proportions are representative for 2005 and 2010, total numbers of tractors were calculated by multiplying the index St value by the sum of tractors in countries with the data available for a given year within particular groups. Such calculations were not necessary for Japan (IIa) and Russian Federation (IV). In these cases the data for all period were available.

Results and Discussion

The estimated number of tractors in use at the world's scale in 2000 amounted to 28,509 thousand units and until 2010 increased to 33,333 thousand (by 17%). In 5 groups of countries, the number of tractors increased by 4.7-114%. The highest increase was noted in the Eastern and Southern Asia. In 4 groups and in Japan decreases have been observed (**Table 1**).

Increase or decrease in numbers of tractors in particular groups does not mean that in all countries in these groups the trends of changes were the same. For instance, in the group I alongside the decrease in the USA, some increase in Canada was noticed. Similar situation was observed in all other groups of countries. During 2000-2010 the number of tractors in use in French agriculture decreased by 33.1%, and in Spanish agriculture increased by 16.7% (group IIb). Similarly, in Polish agriculture the increase by 9.1% was registered whilst in Slovenian one − the decrease by 10.9% (group III). Even in the group VI, characterized in the most dynamic average increase, an exception occurred: reduction in Mongolia by about 30% (the trend similar to observed in Russian Federation and in former Soviet republics in Central Asia).

One of reasons causing reduction of tractor stock in agriculture of developed countries with high level of agricultural mechanization is reduction in the number of farms and growing concentration of land in most of them. Only in limited number of developed countries the opposite trend was observed. This was a case of USA and UK, countries with high level of average size of farms (191 and 72 ha of agricultural area per farm respectively). Then, in spite of decreasing absolute numbers of tractors in such countries, the indexes per 100 farms are growing, that shows an example of 8 countries.

During the years 2000-2010 number of tractors decreased in Japan by 17.3%, in USA by 8.3%, in Denmark by 10,2%, in France by 33.1%, in Germany by 26.9%, in Netherlands by 3.0%, in Sweden by 3.9%. At the same time the number of farms decreased in Japan by 3.2%, in Denmark by 27.2%, in France by 26.2%, in Germany by 25.1%, in Netherlands by 28.8% and in Sweden by

Table 1 Tractors in use by regions (groups of countries)

Group	Thou. units in years			2000 = 100 [%]	
	2000	2005	2010	2005	2010
I	5974.6	5674.8	5621.9	95.0	94.1
IIa	2028.0	1943.0	1678.0	95.8	82.7
IIb	8253.6	8330.0	8640.1	100.9	104.7
III	3291.3	3216.8	3210.5	97.7	97.5
IV	747.0	480.3	330.0	64.3	44.2
V	189.2	160.6	162.0	84.9	85.6
VI	4528.3	6095.8	9690.6	134.6	214.0
VII	1693.1	1869.1	2075.5	110.4	122.6
VIII	146.6	170.1	184.3	116.0	125.7
IX	1657.0	1622.5	1739.6	97.9	105.0

Source: Own estimations basing on: (FAO 2014; Farm Machinery Statistic 2011; Flecker M. 2013; Wiesendorfer et al., 2013; World Bank 2014).

12.7%, whilst in USA increased by 1.6%, and in UK by 22.9%. As a result only in UK and USA significant decrease in numbers of tractors per 100 farms were observed. In France and Germany value of the index decreased only slightly and in other 4 countries, increased by 10.0 to 36.2% as noted in **Table 2**.

Growing concentration of land and scale of production requires that machinery of higher working capacity is necessary. Therefore, the power of tractors in use successively grows. For instance, during 2000-2010 average power of tractors increased in Japan by 14.1%, in the USA by 5.3%, in UK by 16.3%, in France by 66.2%, in Italy by 7.7% and in Poland by 18.2%. As a result, the power of tractor fleet in most of the countries was higher in 2010 than in 2000, in spite of decreases in numbers of tractors in use in Japan, USA, UK, France and Germany. Besides, in USA, Canada, Japan, Europe and many countries in other regions, the area of agricultural land has decreased. As a result, the decrease of absolute number of tractors does not always mean the parallel decrease in value of indexes related to area of arable land and permanent crops as well as to the agricultural area (**Table 3**).

In spite of decrease in numbers of tractors by 5.9% in industrialized countries with an average farm sizes over 100 ha of agricultural area, the number of tractors per 100 ha of arable land and permanent crops in 2010 increased by 2.4% in comparison with situation in 2000. Instead, in Latin America and Caribbean countries decrease of the number of tractors per 100 ha of arable land and permanent crops was observed in spite of increase of the absolute number of tractors by 5.9%. The reason was the decrease of arable land and permanent crops in some groups and the increase in the other ones. During the years 2000-2010 in Japan and Russian Federation as well as in countries of groups I, IIb, III and VII the area of arable land and permanent crops decreased, relatively by 5.0; 4.0; 8.3; 3.4; 6.9 and 0.5%. Instead, in groups V, VI; VIII and IX increases by 6.5; 0.9; 20.5 and 15.9% were observed. Like in a case of number of tractors in use, also dynamic and direction of changes concerning the area of arable land and permanent crops is differentiated by countries within particular groups.

Table 2 Tractors in use per 100 farms in selected countries

Country	Tractors in use [units·100 farms^{-1}]			2000 = 100	
	2000	2005	2010	2005	2010
Japan	86.8	99.0	102.9	114.0	118.5
USA	221.5	213.0	199.9	96.2	90.3
Denmark	213.1	219.4	262.9	103.0	123.4
France	222.4	222.7	219.9	100.2	98.9
Germany	257.6	242.4	256.4	94.1	99.5
Netherlands	146.2	176.7	199.1	120.8	136.2
Sweden	202.7	210.5	223.0	103.9	110.0
UK	214.4	160.4	154.5	74.8	72.1

Source: own estimations basing on: (FAO 2014; Farm Machinery Statistic 2011; Eurostat 2014).

Table 3 Power of tractor fleet as related to area and number of farms in selected countries

Country	Tractors in use per 100:	Years			2000 = 100 [%]	
		2000	2005	2010	2005	2010
Japan	ha of arable land and permanent crops	883.6	949.8	878.1	107.5	99.4
	ha of agricultural area	765.7	822.1	760.2	107.4	99.3
	farms	15.8	19.6	21.4	124.1	135.3
USA	ha of arable land and permanent crops	103.9	106.0	110.6	102.0	106.4
	ha of agricultura area	44.9	43.2	57.8	96.2	128.7
	farms	85.8	84.7	81.6	98.7	95.1
UK	ha of arable land and permanent crops	277.2	280.5	281.6	101.2	101.6
	ha of agricultura area	96.9	95.6	98.3	98.6	101.5
	farms	70.5	56.5	59.1	80.2	83.9
France	ha of arable land and permanent crops	247.7	318.7	319.6	128.6	129.0
	ha of agricultura area	163.3	211.8	212.7	129.7	130.3
	farms	73.1	110.4	120.1	151.0	164.4
Germany	ha of arable land and permanent crops	208.3	392.2	330.1	188.3	158.5
	ha of agricultura area	146.7	278.7	238.1	190.0	162.3
	farms	53.0	121.7	132.9	229.5	250.6
Italy	ha of arable land and permanent crops	636.4	783.4	897.3	123.1	141.0
	ha of agricultura area	440.5	549.3	603.0	124.7	136.9
	farms	32.0	46.8	53.3	146.4	166.6
Poland	ha of arable land and permanent crops	298.3	388.2	487.1	130.1	163.3
	ha of agricultura area	232.1	305.5	377.5	131.6	162.6
	farms	20.7	27.2	35.3	131.4	170.5

Source: own estimations basing on: (FAO 2014; Farm Machinery Statistic 2011; Eurostat 2014).

The highest number of tractors per 100 ha of arable land and permanent crops was in Japan and the lowest in Sub-Saharan Africa (**Table 4**).

In industrialized countries with an average farm sizes over 100 ha of agricultural area (group I) Western Europe and Israel (group IIb), Central and Eastern Europe (group III), South and East Asia and Pacific islands (group VI), and Middle East and North Africa (group VII) increases in the number of tractors per 100 ha of arable land and permanent crops were noted. Instead in Japan (IIa), Russian Federation (IV), and former Asian Soviet Republics (V) decreases by 13.0-45.2% were observed. In Sub-Saharan Africa (VIII) the value of the index did not changed during the studied period.

Like in a case of the number of tractors per 100 ha of arable land and permanent crops, the indexes related to the agricultural area are affected by changes of the area in particular regions. In Japan, Russian Federation as well as in groups I, IIb, III and VII the decreases of the area, by 4.9; 1.6; 6.2; 6.4 and 6.2% respectively, were noticed. Instead, in groups V, VI; VIII and IX increases by 0.9; 0.3; 4.4 and 4.6% were observed. As a result, in spite of reduction in the number of tractors in the group I, the growth of the index related to the agricultural area by 12.3% was observed. The highest number of tractors per 100 ha of agricultural area, both in 2000 and 2010, was in Japan and the lowest in Sub-Saharan Africa (**Table 5**).

Low values of the number of tractors per 100 ha, both of arable land and permanent crops and agricultural area, in groups I and V as well as in Russian Federation are due to domination of large farms. In general, the values of the indexes are decreasing along with growing size of farms. Instead, the number of tractors per 100 farms is growing along with increasing of the farm size (Pawlak, 2011; 2013; Wojcicki, 2013). However, in case of Russia and the former Asian Soviet Republics, there are still insufficient equipment in means of mechanization (Marchenko, 2013).

As compared to situation presented in earlier paper (Pawlak *et al.*, 2002), the most dynamic growth of tractor fleet was noted in East and South Asia (group VI). This concerns especially China and India, owing in 2010 about 75% of total tractors in the region. The Sub-Saharan Africa emerged the worse equipped region in spite of almost 26% growth in the number of tractors. During the years 1961-2000 the growth in number of tractors in Sub-Saharan Africa amounted to 28% and it was by 441 percentage points lower as compared to Latin America (Opara, 2013). During the years 2000-2010 the rate of the growth in Sub-Saharan Africa was by 21 percentage points higher than in Latin America and Caribbean countries. However, the relatively high increase in this region within 2000-2010 was due to very low equipment in the reference period (year 2000). Estimated increase during 2000-2010 in absolute value amounted only about 38 thousand units. Under such circumstances the animal traction is still the most important in agriculture of the region (Makki, Jamaa, 2012).

Many experts (Bani and Dorvlo, 2013; Carroll, 2013; Hay, 2013; Khan and Rudra 2013; Kic and Zewdie, 2013; Lantin, 2013; Mani, 2013; Nath S. 2013) point that the improvement in countries with low level of the farm mechanization is possible under condition of rational transfer of technology, knowledge and experience from developed countries. For countries with small-scale agriculture, it is especially important to have cooperation with Japan, having excellent achievements in transforming its smallholding agriculture into knowledge intensive mechanized enterprises (Opara, 2014).

Table 4 Tractors per 100 ha of arable land & permanent crops

Group	units·100 ha^{-1}			2000 = 100 [%]	
	2000	2005	2010	2005	2010
I	2.049	2.000	2.103	97.6	102.6
IIa	48.455	47.841	42.200	98.7	87.1
IIb	9.576	9.842	10.374	102.8	108.3
III	2.998	3.106	3.140	103.6	104.7
IV	0.589	0.389	0.271	66.0	46.0
V	0.581	0.480	0.468	82.6	80.6
VI	1.036	1.390	2.196	134.2	212.0
VII	2.002	2.174	4.176	108.6	208.6
VIII	0.125	0.129	0.131	103.2	104.8
IX	1.129	0.983	1.023	87.1	90.6

Source: Own estimations basing on: (FAO 2014; Farm Machinery Statistic 2011; Flecker M. 2013; Wiesendorfer et al., 2013; World Bank 2014).

Table 5 Tractors per 100 ha of agricultural area

Group	units·100 ha^{-1}			2000 = 100 [%]	
	2000	2005	2010	2005	2010
I	0.568	0.549	0.638	96.7	112.3
IIa	41.988	41.411	36.534	98.6	87.0
IIb	5.664	5.8	6.153	102.4	108.6
III	2.269	2.321	2.363	102.3	104.1
IV	0.344	0.223	0.154	64.8	44.8
V	0.069	0.058	0.058	84.1	84.1
VI	0.488	0.656	1.04	134.4	213.1
VII	0.732	0.855	0.957	116.8	130.7
VIII	0.025	0.028	0.03	112.0	120.0
IX	0.263	0.251	0.264	95.4	100.4

Source: Own estimations basing on: (FAO 2014; Farm Machinery Statistic 2011; Flecker M. 2013; Wiesendorfer et al., 2013; World Bank 2014).

Conclusions

There are big regional differences in the level of equipment in agricultural tractors. These are due to local conditions (structure of use of agricultural area, size of farms) and to degree of economic and technological development.

During the years 2000-2010 the highest increase of the level (by 114%) was noted in the Eastern and Southern Asia. Sub-Saharan Africa is still the worse equipped region in spite of about 26% growth in number of tractors.

In countries with low level of the farm mechanization improvement of situation is possible under condition of rational transfer of technology, knowledge and experience from developed countries.

For countries with small-scale agriculture especially cooperation with Japan is important that has excellent achievements in transforming its smallholding agriculture into knowledge intensive mechanized enterprises.

Results of this study can be used as a base for evaluation of effect of the level of mechanization on productivity of land and labor in agriculture.

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NEWS

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Storage and Handling Engineering of Sugarbeet Pulp as a Feedstuff for Animal Feeding

by
Said Elshahat Abdallah
Associate Professor
Department of Agricultural Engineering
Faculty of Agriculture, Kafrelsheikh University
Kafr Elsheikh 33516
EGYPT
saidelshahat@agr.kfs.edu.eg

Wael Mohamed Elmessery
Lecturer
Department of Agricultural Engineering
Faculty of Agriculture, Kafrelsheikh University
Kafr Elsheikh 33516
EGYPT

Abstract

Sugarbeet is one of the main sugar crops in the world. In the search for sustainability and economic value, the complete utilization of the crop is necessary. In addition to sugar production, sugarbeets can provide many value-added by-products for animal feeding. One of major by-products in sugarbeet plants is sugar beet pulp that has a fairly high moisture content of 75-85%, which makes sugarbeet pulp storage a challenge, drying and palletization are the consequence important processes for further appropriate packaging and exportation. Sometimes the risk of pellets marketing internationally affects pellets handling, especially the storage for a while until marketing circumferences improved, even for local consumption or exportation. The need for a suitable technology is emerged for that reason; moreover this by-product has a nutritious value close to other traditional feeding crops. In Egypt nowadays the silos are considered to be a vital facility for crops storage for international trading. So this paper aims to design a proper silo for sugarbeet pulp storage. Proper silo is depending basically on the strength and flow properties of sugarbeet pulp pellets under operating conditions. After studying the engineering characteristics of sugarbeet pulp pellets, yield locus was implemented for determining the flow properties according to Jenike principals for proper silo design and examining the discharging behavior visually; Analytical and experimental procedures have been used to determine the values of pressures inside silos and for predicting the characteristics of the flow pattern. A model silo for assaying pressure in this silo basically consists of cylindrical silo equipped with load cells to measure pressure and variable-frequency drives connected to each of the electric motors driving the filling and discharge screw conveyors, in order to investigate the effect on pressure of the speed at which the silo is filled or discharged. These runs of experiments were conducted at the Department of Agricultural Engineering, Kafrelsheikh University during spring and summer seasons of the year 2015. As a result of this investigation, the flow index of sugar beet pulp pellets was 14.5 and was classified as a cohesive and free flowing material. The silo wall-pellets friction angle was of 20°. Pellets discharging behavior represents mass flow pattern at each height at half angles of 10° and 20° and discharging opening dimensions of 0.17 and 0.13 m. Stress distribution analysis shows the highest values of bending moment at hopper section of 10.2N/mm^2 and tensile stress of 2.014N/mm^2 at silo section.

Keywords: Sugarbeet pulp pellets, Engineering properties, Flow characteristics, Silo pressure distribution analysis, Storage engineering.

Introduction

Once the sugar is extracted from sugarbeet, the beet pulp mechanically pressed, dried to reduce the moisture content and then pelletized is normally fed to animals (Asadi, 2007). Sugarbeet pulp also contains a significant fraction of cell wall polysaccharides including pectin and dietary fiber. Utilization of the co-products reduces waste and adds value to the crop (Broughton *et al.*, 1975). Sugarbeet pulp is a valuable by-product from the manufacturing of sugarbeet. Its carbohydrate (cellulose, hemicellulose, pectin, and others) contents have been reported to be as high as 85% (w/w, dry basis) and its lignin content as low as 1-2% (w/w, dry basis). It also contains 10-15% protein (w/w, dry basis) (Micard *et al.*, 1996). Egypt planted 517 thousand feddans of sugarbeet crop and produced 9.31 million tons

Nomenclature

F	Hopper pressure ratio $F = P_v / P_h$ that is dependent on hopper geometry and solids properties (measured empirically), dimensionless
β	Hopper half angle, degree
K	Lateral pressure ratio was dependent on solids properties in the analysis of the pressures on vertical walls, dimensionless
K_a & K_p	Active and passive limits for lateral pressure ratio, dimensionless
γ	Sugar beet pulp pellets specific weight, N/mm^3
ϕ_i	Internal friction angle of pellets particles, degree
U	Perimeter against silo wall, mm
z	Slice under analysis depth, the origin of the vertical coordinate at the centroid of the top pile of solids (equivalent surface), mm
A	Horizontal area of the silo, m^2
τ	Frictional shear stress (frictional traction) on the silo wall, N/mm^2 $\tau = \mu_f P_h$
P_{v0} & P_{h0}	Mean vertical and horizontal stresses in the solid that is reached asymptotically at great depth, N/mm^2
z_0	Janssen reference depth (defines the rate at which the asymptote is approached), m
σ_1	Consolidation stress, kPa
σ_c	Unconfined yield stress, kPa
r_w	Hydraulic radius of horizontal cross section of storage space, m
C_d	Overpressure factor, used to consider increases of pressure occurring during discharge, converting from static pressure to design pressure, dimensionless
C_f	Safety factor of friction force, used to long-term design friction force between silo wall and granular materials, dimensionless
C_i	Impact factor, used to consider pressure increase due to sudden filling, converting from static pressure to design pressure, dimensionless
C_L	Ratio of the local pressure to the design horizontal pressure, dimensionless
l_c	Perimeter of horizontal inside cross section of silo and hopper wall, m
P_f	Friction force of unit area of silo wall surface at depth x, N/mm^2
P_h	Horizontal pressure of unit area at depth x due to stored material, N/mm^2
P_v	Vertical pressure of unit area at depth x due to stored material, N/mm^2
P_a	Pressure normal to the surface of inclined hopper wall, N/mm^2
dP_h	Design horizontal pressure of unit area, N/mm^2
dP_L	Design local horizontal pressure of unit area, N/mm^2
dP_v	Design vertical pressure of unit area, N/mm^2
dP_a	Design normal pressure of unit area to hopper wall, N/mm^2
α	Angle of hopper from horizontal, degree
μ_f	Coefficient of friction between stored material and wall or hopper surface, dimensionless
$F_{h1,t}$ - $F_{h2,t}$ - $F_{h3,t}$	Value of the force recorded by load cell for h1, h2 or h3 at time t, kN
$F_{L1a,t}$ $F_{L1b,t}$ $F_{L1c,t}$	Vertical force exerted on the load cells located at level L1 and position a, b or c at each time t, kN
$F_{L0a,t}$ $F_{L0b,t}$ $F_{L0c,t}$	Vertical force exerted on the load cells located at level L0 and position a, b or c at each time t, kN
Ph1@0.70 Ph2@0.60 Ph3@0.45	Normal wall pressure at time t on the load cell for h1, h2 or h3, kN/m^2
ph@ut	Value of mean normal hopper wall pressure at time t at the silo-hopper transition, kN/m^2
$p_{vt,t}$	Vertical stress in the stored material at the silo-hopper transition at time t, kN/m^2
$p_{w,t}$	Mean value of wall frictional traction stress at time t, kN/m^2
S_c	Cylinder surface area in contact with stored material at time t, m^2
S_h	Cylinder wall surface acting on each load cell, m^2
S_{h0}	Hopper wall surface acting on each load cell, m^2
W_{hsm}	Weight of stored material between the outlet and the silo-hopper transition, zero in the case of flat bottom, kN
W_T	Total weight of stored material, kN
V_c	Internal cylinder volume, m^3
V_h	Internal hopper volume, m^3

of sugarbeet in 2014 (MOA, 2014) which resulted in more than 0.5 million dry tons of sugarbeet pulp after sucrose extraction (Doran *et al.*, 2000). The profitability of selling sugarbeet pulp as animal feed depends greatly on the economics of the energy and feed industries since its processing, including drying, pelletizing, and transporting, is energy-intensive (Rorick *et al.*, 2009). In many parts of the world, utilization of sugarbeet pulp is an economically marginal part of beet sugar processing due to the high drying cost and transporting (Doran *et al.*, 2000). Drying of sugarbeet pulp is common as it avoids carbohydrate loss due to microbial activity. However, in most countries this method is too expensive. Solar drying, in Egypt, is available during summer season and can starting efficiently in April, the peak month of sugarbeet harvesting. The storage is an advantageous when sugarbeet pulp is intended to be available all around the year to overcome forage shortage in any time of the year due to the low cost of production and sugar process factories have to export all the production of pellets to European markets, especially Netherlands, for horse feeding. For these reasons, it is worth investigating pellets storage in silos to minimize sugarbeet pulp carbohydrate loss. The design of bulk solids handling plant requires knowledge of the strength and flow properties of the bulk solids under operating conditions. Jenike, 1964 was the first to establish the fundamental methods for determining the flow characteristics of bulk materials. The procedures delineated by Jenike have become a standard method D-6128 (ASTM International, 2006). To analyze the flow of solids in bins and silos, and to develop a model of flow and no-flow, Jenike used the principles of plastic failure with the Mohr-Coulomb failure criteria (Thomson, 1997). The shear stress (τ) generated along a defined plane depends on the normal stress (σ) exerted on this plane. If a material is subjected to a shearing action, a characteristic relation is obtained between normal and shear stresses for each material. This relationship is graphically shown in σ-τ coordinates (namely Mohr diagrams) and the curve - always a straight line- obtained finally is the yield locus for a bulk material. All of the flow parameters of bulk materials are obtained from these yield loci (Arnold *et al.*, 1989). A yield locus is an important tool in determining the flow properties of bulk materials. The flow index (ff_c), is defined as the inverse slope of the flow function (FF), is used to classify bulk material flowability with higher values representing an easier flow (Doran *et al.*, 2000). If the flow index $ff_c < 1$ the flowability is hardened, $ff_c < 2$ the flowability is very cohesive, $ff_c < 4$ the flowability is cohesive, $ff_c < 10$ is easy flowing and $ff_c > 10$ is free flowing. The important factor to be considered when calculating silos is the h_c/d_c ratio (cylinder height divided by internal diameter). The EN 1991-4, 2006 classifies silos as: slender silos ($2 \leq h_c/d_c$), intermediate slenderness silos ($1 < h_c/d_c < 2$), squat silos ($0.4 < h_c/d_c \leq 1$) and retaining silos ($h_c/d_c \leq 4$), and proposes methods for calculating the different pressures according to the class to which the silo belongs. Traditionally, analytical procedures have been used to determine the values of pressures inside silos and for predicting the characteristics of the flow pattern (Jenike, 1964). Nowadays other numerical techniques were developed for the study of the pressures and flow characteristics in silos. One of these is the Finite element method (FEM) (Zienkiewicz and Taylor, 2005), which has been used with relative success to predict the pressures and flow patterns generated in silos (Sadowski and Rotter, 2011a, 2011b).

So the main aim of this investigation is to design an appropriate silo for dried sugarbeet pulp pellets storing for local consumption rather than exportation in sugarbeet process plants. To achieve the main aim, the specific objectives are scheduled as follows:

1) Study the engineering properties of sugarbeet pulp pellets for silo manufacturing.
2) Pre-exam the discharging behavior of sugarbeet pulp pellets visually with different hopper angles and discharging opening dimensions.
3) Investigate analytically stress distribution of silo's wall and hopper of sugarbeet pulp pellets at static conditions.
4) Manufacture a model silo to investigate stress distribution on silo wall and hopper during short term storage, filling and discharging operations.

Materials and Methods

Silo Designing for Mass Flow

The approximate height of the cylinder section needed to store the desired capacity (initially ignoring the capacity in the hopper section) is simply (Thompson, 1984):

$$H = m / (p_{avg} A) \quad \text{..... Eqn. 1}$$

Where; H is the cylinder height (m), m is the mass to be stored (kg), p_{avg} is the average bulk density (kg/m^3), and A is the cross-sectional area of the cylinder section (m^2). Silo design depends basically on the engineering properties of the agricultural material which will be stored (sugarbeet pulp pellets). Jenike type shear tester was used in the experimental tests to determine the flow properties of sugarbeet pulp pellets (ASTM International, 2006). The shear test generally consists of two steps; the first step is the consolidation (pre-shear) step in which a critically consolidated sample is prepared. The second step is the attainment of steady state flow in the shear cell which is called as shear step. Shear points on yield locus

Table 1 Adopted values for parametric analysis

Model	Hopper half angle, β	Discharging opening dimension, B
M1	10°	0.17 m
M2	20°	0.13 m
M3	40°	0.07 m
M4	60°	0.03 m

with failure point (require for material to flow) shear stress values were obtained for a defined normal stress at a selected pre-shear stress. Each point of yield locus was repeated two times throughout the experimental tests. It can be seen from the form and position of yield locus, in the Mohr diagram, which type of material is. A cohesive bulk material is named as Coulomb solid and expressed by a linear yield locus in soil mechanics:

$\tau = tan\phi_i\, \sigma + C$ ..... Eqn. 2

Where; τ is the shear stress, σ is the normal stress, C is the cohesion factor or coefficient and ϕ_i is the angle of the internal friction of the material. ϕ_i is an indication of the friction coefficient within the material. It has a constant value as it changes at low consolidation stress levels in the case of curved yield locus (Jenike, 1961). The limits for axi-symmetry or conical hoppers depend on the hopper half-angle β, the angle of internal friction ϕ_i and the wall friction angle μ. Once the wall friction and internal friction angles have been determined by laboratory tests at Rice Mechanization Center (RMC) in Meet Eldeebah Village, Kafr Elsheikh governorate, Egypt throughout the year of 2015, the hopper half angle can be determined by Jenike's graphics (Schulze, 2007). In practice, the actual opening dimension B is made larger than B_{min} in order to achieve the desired mass flow rate. For the enlarged opening, the actual flow factor ff_c is applied and the major consolidation pressure at the outlet increases to the value corresponding to the actual opening dimension B.

$ff_c = \sigma_1 / \sigma_c$ ..... Eqn. 3

Where; σ_1 is the unconfined yield stress and σ_c is consolidation stress.

Direct Observation of Discharge

It is possible to visually assess the predicted flow pattern within the silo. To facilitate this task, all particles in the silo were divided into different horizontal layers at the beginning of the discharge process. These layers were colored with four contrasting colors as shown in **Fig. 1**, through which those particles movement can be easily identified. The behavior investigation of manufactured apparatus for sugarbeet pulp pellets discharging was conducted, through an experimental procedure, in the Laboratory of Agricultural Engineering Department, Faculty of Agriculture, Kafrelsheikh University, Egypt during spring and summer seasons of the year 2015.

Velocity Profile and Mass Flow Index (MFI)

For each model defined in **Table 1**, three control volumes (CV1, CV2 and CV3) at different silo heights (H_{CV1} = 0.5m, H_{CV2} = 0.2 m and H_{CV3} = 0.1 m) of the model have been considered in **Fig. 1**. Each control volume has a vertical graded scale where the vertical velocities of the particles are spatially averaged at each period during the simulation by splitting a recorded video each 0.1 second using a digital camera (Kodak AF 3x Optical Aspheric Lens 12 Mega Pixels). Thus, the velocity profiles at these locations at a particular simulation time can be obtained by plotting the vertical velocity in each control volume against the horizontal coordinate (x) associated to each control volume's central point. Additionally, each velocity profile can be summarized through the Mass Flow Index (MFI), which is defined as

MFI = v_{wall} / v_{cent} (Rotter, 2001). For every control volume, v_{wall} and v_{cent} are, respectively, the particle velocity at the extreme silo and at the central silo. According to (Johanson and Jenike, 1962), values of MFI > 0.3 are indicative of mass flow. Whereas values of MFI < 0.3 are indicative of funnel flow. In the case of the control volume CV3, the value of the velocity v_{wall} was calculated from the component parallel to the hopper wall.

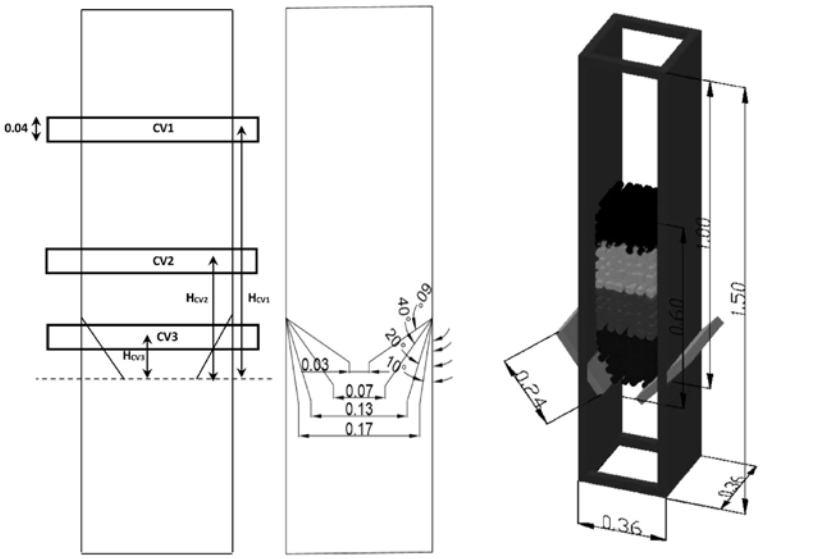

Fig. 1 The manufactured apparatus for sugarbeet pulp pellets discharging behavior investigation

Parameters Definitions

The nomenclature employed in the current research follows the Eurocode and therefore the denotations of parameters are illustrated in **Fig. 2**. However, this article also includes specific aspects which are not considered in the code, and these different parameters are defined in **Fig. 2**.

Silo Stress Distribution Investigated by Analytical Methods

Pressures and friction forces of static stored materials

Static pressures exerted by stored material at rest should be calculated using the following methods: The vertical pressure, Pv, at depth *x* below the surface of the stored material is calculated using equation 4. Silo stress distribution analysis could be estimated through series of equations defined by (Architectural Institute of Japan, 2010) as follows:

$P_v = (\gamma.r_w) / (\mu_f.K) (1 - e^{(-\mu_f.K.x) / r_w})$ ..... Eqn. 4

If the mean vertical stress in the solid P_v is taken as zero at some reference height $z = 0$, theory of Rankine, defined two limiting values of *K*. These are limiting values because, at these values, the solid is ready to be deformed by shearing into a different shape. They are the Rankine active and passive limits, given by:

$K = (1-\sin\phi_i) / (1 + \sin\phi_i)$ *where; 3.0* $\geq K \geq$ *0.3* ..... Eqn. 5

In which $r_w = A / l_c$

The horizontal pressure, P_h, of a unit area of silo wall at depth *x* from the free surface is obtained from equation 6:

$P_h = K_s \times P_v$ ..... Eqn. 6

The friction force, P_f, of a unit area of silo wall at depth *x* from the assumed free surface can be calculated by:

$P_f = \mu_s \times P_h$ ..... Eqn. 7

The static unit pressure, P_a, normal to the surface inclined at angle α to the horizontal at depth *x* below the surface of stored material is obtained from equation:

$P_a = P_h.\sin^2\alpha + P_v.\cos^2\alpha$ ..... Eqn. 8

Design Pressures and Forces Exerted by Stored Materials

Design pressures should be obtained by multiplying the static pressures by the overpressure correction factor C_d or impact factor C_i in accordance with the appropriate equations 9, 10 or 11.

$dP_v = C_i.P_v$ for silo wall

$dP_v = C_i.P_v$ for hopper, whichever is greater

$dP_v = C_d.P_v$ for hopper, whichever is greater

.....Eqn. 9

$dP_h = C_d.P_h$ for silo wall ..... Eqn. 10

$dP_a = C_i.P_a$ for hopper, whichever is greater

$dP_a = C_d.P_a$ for hopper, whichever is greater

..... Eqn. 11

The impact factor, Ci, should be used to consider the material properties, the charging method and the charging rates, and should be taken a value between one and two. According to **Table 2**, Cd value taken is two.

Local pressure is applied to the partial area of the silo wall of 0.1 of silo wall diameter width. A set of pressures compressive directions or tensile ones both, is applied to any point symmetric locations of silo wall. Local pressure dP_L is obtained by equation 12:

$dP_L = dP_h.C_L$ ..... Eqn. 12

C_L (ratio of the local pressure to the design horizontal pressure) values were computed according to (Architectural Institute of Japan, 2010) for the silo as the following **Table 3** and **Fig. 3** based on the height of the location from the bottom end of the silo (x).

Vertical long-term design force dN_m per unit length of silo wall horizontal section, at depth *x* from free surface, should be computed as shown in equation 13.

$dN_m = (\gamma.x - P_v).r_w.C_f$ ..... Eqn. 13

Where C_f is taken as both of 1.0 and more than 1.5, because either two cases may generate the larger stress. The axial force in the direction of generator on the hopper wall horizontal section per unit length, N_φ, and the tensile force in the circumferential direction, N_θ, are calculated using equations 14 and 15 respectively (EN 1991-4, 2006).

$N_\phi = (W_h + W_s) / (l_c.\sin\alpha) + (dP_v.d') / (4.\sin_\alpha)$ ..... Eqn 14

$N_\theta = (dP_a.d') / (2.\sin\alpha)$ ..... Eqn. 15

Where W_h is the weight of the

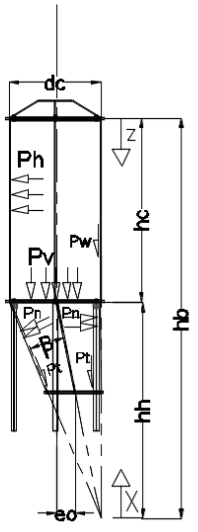

Fig. 2 Depicted silo for parameters definition

Table 2 Minimum required values of overpressure factor C_d

For $^{hb}/_{d} \geq 4.0$	$C_d = 2.0$
For $4.0 > {}^{hb}/_{d} > 1.0$	$C_d = {}^{4}/_{3} + {}^{hb}/_{6d}$
$^{hb}/_{d} \leq 1.0$	$C_d = 1.5$

Table 3 C_L values

At x = 0 m to x = 0.75 m		C_L = 0.275		At x = 0.75 m to x = 1.5 m		C_L = (1.5-x) / tan70	
x, m	C_L	x, m	C_L	x, m	C_L	x, m	C_L
0.05	0.275	0.2	0.275	0.8	0.255	1.2	0.109
0.10	0.275	0.4	0.275	0.9	0.219	1.4	0.036
0.15	0.275	0.6	0.275	1.0	0.182	1.5	0.000

contents of the hopper beneath the section, N; W_s is the weight of the empty hopper beneath the section, N; l_c is the perimeter of the hopper at the section level, mm; d' is the diameter of the hopper at the section level, mm; α is the slope of the hopper wall, degree; dP_v is the design vertical pressure of unit area at the section level, N/mm^2; dP_a is the design normal pressure of unit area to hopper wall at the section level, N/mm^2.

The maximum bending moment using the simple ring model, loaded with a pair of normal local force at opposite sides, is given by equation 16.

$M_0 = 0.318 \times 0.1d \times dP_L \times (d/2)$ ..... Eqn. 16

Where M_0 is the bending moment per unit width of the ring calculated using simple ring model and d is the silo wall diameter, m.

For steel silos, approximate estimation of the maximum bending stress (moment) is given by multiplying the coefficient "k" below by the "M_0" above in some cases defined below. High rigidity boundary cases, with stiffening beams at the boundary, roofs, hoppers e.g., are assumed.

i) The local stress coefficient "k" is applicable when $h_m/d \leq 5$, $d \leq 10$ m and $t \leq 20$ mm
ii) For each plate thickness of the silo wall, the location (height) where the maximum bending stresses should be checked.
iii) The local stress coefficient "k" is given by the equation 17 as:

$k = 0.1 + 0.05 (h_m / (d - 2))$ Eqn. 17

The bending moment Mb is given by the equation 18 as:

$M_b = kM_0$ ..... Eqn. 18

Where M_b is the bending moment per unit width of the silo wall for which the effect of rigid boundaries is approximately considered.

The axial stress on the section of the hopper wall in the direction of generator, σ_φ, and the tensile stress in the circumferential direction, σ_θ, are calculated using equations 19 and 20 respectively.

$\sigma_\phi = (W_h + W_s) / (l_c.t_2.\sin\alpha) + (dP_v.d') / (4.t_2.\sin\alpha) \leq f_t$ ..... Eqn. 19

$\sigma_\theta = (dP_a.d') / (2.t_2.\sin\alpha) \leq f_t$ ..... Eqn. 20

Where f_t is the allowable tensile stress, N/mm^2 and t2 is the silo wall thickness, mm.

Finite Element Analysis Using SAP2000 Program

A validated numerical analysis (Finite element method) as defined in (EN 1993-1-6, 2007) implemented by SAP2000 software package was used to analyze the internal vertical and horizontal forces of silo's shell.

Silo Stress Distribution Investigated Experimentally

The geometry and dimensions of the model silo are selected based on the information gathered about sugarbeet pulp pellets as shown in **Fig. 4**. The silo is cylindrical, with a central hopper and a roof at the top. The silo body (a vertical cylinder), the hopper and the roof are independent and can be dismantled. Cylindrical steel silo walls should be so proportioned that the basic design requirements for the ultimate limit states given in EN 1993-1-6, 2007 are satisfied. So the material selected is from galvanized steel S320GD (Zinc-coated) of minimum tensile stress 390MPa. Hopper and roof reinforcement rings were of 50 mm wide and 10 mm thick. Given the dimensions and the type of material used for the walls, the silo can thus be considered a rigid, smooth-walled steel silo. As both lateral pressures and vertical forces measured at different points of the silo walls, it is possible to obtain values for horizontal and vertical pressures and for wall friction. Therefore, the

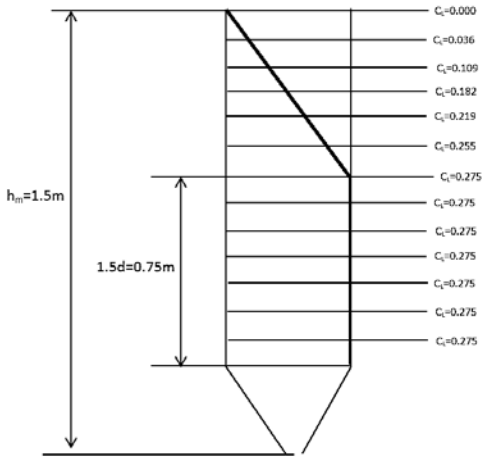

Fig. 3 C_L values

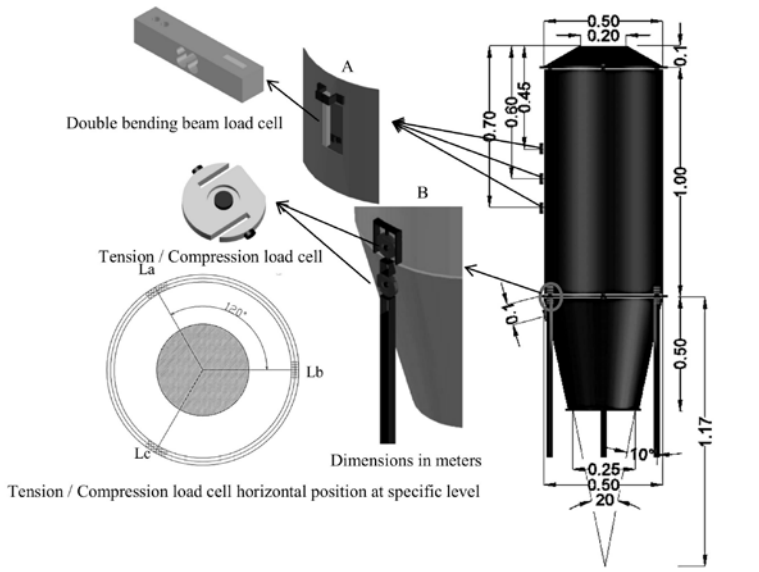

Fig. 4 Solid view of the experimental silo: A- Double bending load cell panel; B- Tension/compression load cell window.

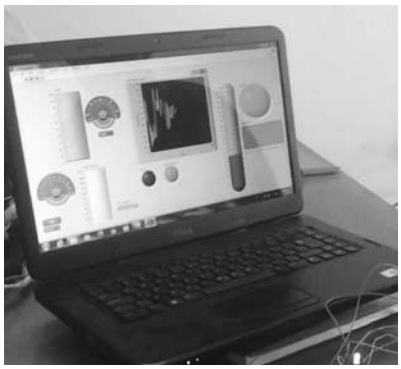

Fig. 5 Executer program for silo filling and discharging operations and load cells data acquisition

Table 4 Engineering properties of the sugarbeet pulp pellets

Material parameter	Range of values analyzed	Values obtained by experimental data
Elasticity module of stored material *E*, kPa	5,000	5,000
Material densityρ, kg m^{-3}	600-700	672.67
Poisson ratio of material, v, dimensionless	0.2-0.4	0.3
Internal friction angle ϕ_i, degree	25°-33°	30°
Wall-grain friction angle μ, degree	20°	20°
Dilatancy angle φ, degree	0-19	2.5
Pellets diameter, mm	8	8

mean friction coefficient produced at the silo wall can be determined.

Measuring Horizontal Pressures

The pressures exerted on the cylinder wall are measured at different heights. Pressures exerted on the hopper are measured immediately below the transition, at the prolongation of the generatrices for measuring the cylinder. To measure normal wall pressures at different points, double bending beam load cells are used. To this end, openings are made in the wall, into which panels of exactly the same shape as the opening, made of the same material as the wall and of the same thickness, are inserted. These panels are completely flush with the inner side of the silo wall. Load cells parallel to the cylinder are connected to these panels, in order to measure the horizontal force exerted on a known surface area. A very small tolerance is allowed between the edges of the panels and the wall in order to avoid friction and ensure that the panel rests only on the double bending beam load cells, **Fig. 4A**. Data obtained from these double bending load cells are for horizontal forces at these points. To calculate the horizontal pressure, equation 21 was used.

$Ph1@0.7 = F_{h1,t} / S_{h1}$

$Ph2@0.6 = F_{h2,t} / S_{h2}$

$Ph3@0.45 = F_{h3,t} / S_{h3}$

And in the case of normal hopper wall pressure: Eqn. 21

$Ph@ut = F_{h0,t} / S_{h0}$

Measuring Vertical Forces

Vertical forces are measured by tension/compression load cells (Molenda *et al.*, 2009). Measurements are taken at points located at two different heights L0 and L1 by three load cells placed at each height, 120° apart around the circumference of the cylinder, La, Lb and Lc as depicted in **Fig. 4**. The hopper is mounted on three load cells at level L0 thus enabling measurement of the total weight of the stored material. The cylinder is mounted on a further three load cells at level L1, located above the previous three ones, enabling measurement of the vertical force exerted on the wall, **Fig. 4**. This enables the value of the frictional forces to be obtained, which in turn is used to obtain average vertical pressures at a determined level. In addition, this also permits values for the vertical force on the wall at the silo-hopper transition junction caused by friction between the stored material and the cylinder walls to be obtained. The mean vertical pressure of stored material at the silo-hopper transition for each time t, is obtained from readings provided by the tension/compression load cells located at levels L0 and L1, using the following expression, equation 22:

$$p_{vt,t} = (F_{L0a,t} + F_{L0b,t} + F_{L0c,t}) - (F_{L1a,t} + F_{L1b,t}) + F_{L1c,t}) - W_{hsm}) / A \text{ .. Eqn. 22}$$

Wall Frictional Traction

The mean value of the frictional pressure exerted on the cylinder wall by stored material can be obtained for each time, even during filling and discharge, since the evolution over time of the cylinder surface in contact with the stored material is known, constant speed of filling and discharge. Mean frictional pressure is obtained using the following expression:

$$p_{w,t} = (F_{L1a,t} + F_{L1b,t} + F_{L1c,t}) / S_{c,t} \text{ ..... Eqn. 23}$$

Specific Weight of Stored Material

Given that the silo volume is known and the slope angle of the stored material can be measured, the specific weight of the stored material when the silo is full and the stored material is static is obtained from vertical load cell readings from level L0 using the following expression:

$$\delta = (F_{L0a} + F_{L0b} + F_{L0c}) / (V_c + V_h) = W_T / (V_c + V_h) \text{ ..... Eqn. 24}$$

Filling and Discharge Speed Control

Filling and discharge is performed using screw conveyors connected to two AC motors. Filling and discharge speed is controlled by variable-frequency drives (VFD) which regulate conveyor rotation speed.

Data Acquisition and Processing

The analog signal sent by each load cell expressed in mV/V would

Table 5 Nutrition analyses of sugarbeet pulp pellets.

Technical analysis		
Item	Dry basis	As fed
Dry matter	----	90.73%
Moisture content, wb	----	9.27%
Protein, crude	8.29%	7.52%
Fiber, crude	16.97%	15.42%
Fat	1.09%	1.00%
Ash	7.56%	6.86%
Calcium	1.00%	0.91%
Phosphorus	0.07%	0.06%
Potassium	0.56%	0.51%
Nutrition information		
ADF – Acid Detergent Fiber	26.68%	24.22%
NEL – Net Energy Lactation	0.72%	0.65Mcal/lb
NEG – Net Energy Gain	0.46%	0.41Mcal/lb
NEM – Net Energy Maintenance	0.78%	0.71Mcal/lb
TDN - Total Digestible Nutrients	69.40%	63.04%
NFE – Nitrogen Free Extract	66.09%	63.04%
Reducing Sugars	2.60%	2.39%
Sucrose	8.96%	8.15%
TSI – Total sugars as invert	8.23%	7.43%

Table 6 Flow parameters found from yield loci at selected pre-shear stress levels

Moisture content, %wb	Pre-shear Normal stress, kPa	Cohesion (C), kPa	Angle of internal friction(ϕ), degree
4.8	4.12	0.412	32.3
5.1	8.55	0.5388	31.2
5.5	17.96	0.761	31.1
6.2	31.80	0.782	31.0

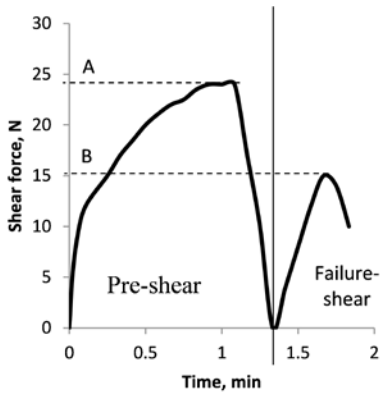

Fig. 6 Pre-shear and failure-shear curve of a sample of dried sugarbeet pulp

be processed by analog digital converter in data acquisition card NI-DAQ 6008 as illustrated in **Fig. 5**. Reading and storing the data sent by load cells, as well motor rotation speed control is performed by a PC using LabView software application designed specifically for this purpose. This application facilities selection of the time interval between readings (from tenths of seconds), storing them in a text file. At the same time, it also provides the ability to control the variable-frequency derives and set the filling or discharge speed desired in each experiment, **Fig. 5**.

Results and Discussion

Engineering Properties of Sugarbeet Pulp Pellets

Tables 4 and **5** show sugarbeet pulp pellets characteristics, engineering properties and their nutritious value. The values obtained by means of laboratory tests were used as a raw data for silo design. **Table 5** shows the nutritious value of the pellets for animal feeding where the mean value of crude protein was of 8.29%.

Flow Properties of Sugarbeet Pulp Pellets Measurement

Instantaneous flow properties (cohesion and angle of internal friction) of sugarbeet pulp pellets were measured at intrinsic moisture contents (low and high moisture contents) by using direct shear tester, as illustrated in **Table 6**. This is characterized by flow function (or flow index). It has been found that cohesion values increase with increasing normal stress values and high moisture content and small particle size also increase the cohesion values. Besides, there is no significant difference between the angles of internal friction values at different stress levels. It can be said that high moisture content and small particle size has an adverse effect on the flow characteristics. The curve of pre-shear and failure shear created that is shown in **Fig. 6** was selected among other three curves based on

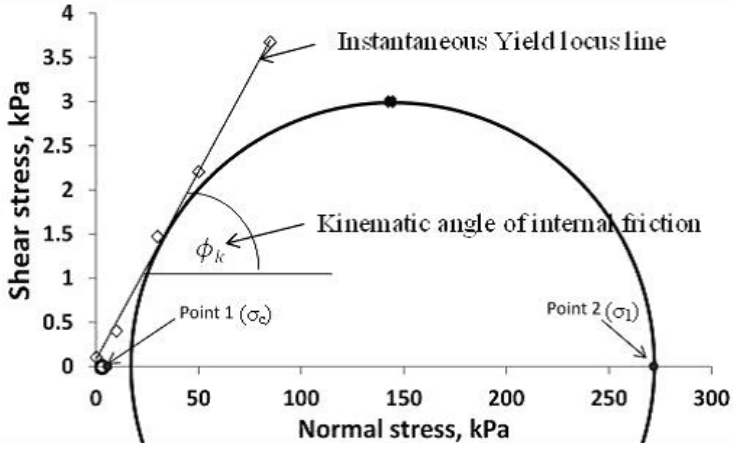

Fig. 7 Yield locus and Mohr-diagram for sugarbeet pulp pellets.

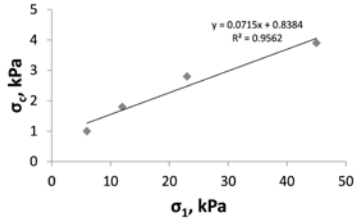

Fig. 8 Sugarbeet pulp pellets flow function

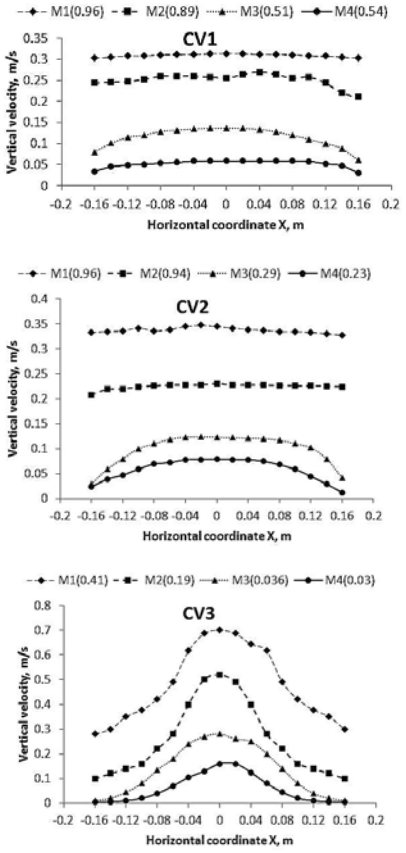

Fig. 9 Mean velocity profiles at levels CV1, CV2 and CV3 for all models with MFI values in brackets

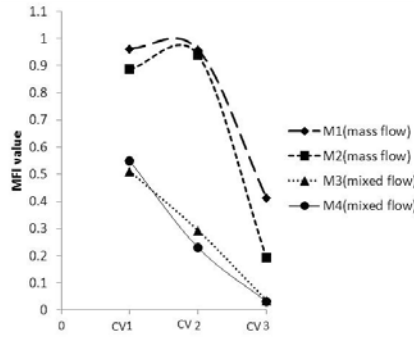

Fig. 10 Mass Flow Index values at different levels of CV1, CV2 and CV3 for all models

pellets response achieving shear steady state, the consolidation and yield loci points (A, B) can be determined by drawing a horizontal line from the pre-shear steady state load (average maximum 4-6 values) to Y-axis (24N), as well as Loci point is 15N. This test was repeated at the same shear load.

Once the points of consolidation and loci were obtained, the yield loci trend line can be drawn through the yield loci dots as shown in **Fig. 7**. After that Mohr circles can be configured, the major circle obtained by yield loci line and consolidation point and failure circle. The smallest one goes through the origin and is tangential to yield loci line. Afterwards the yield locus and Mohr stress circles defining the unconfined yield strength, σ_c, point 1 and the consolidation stress, σ_1, point 2. The ratio of the major consolidation stress point 2 found from the yield locus to the unconfined yield strength point 1 is called the flow factor. A yield locus for a cohesive solid is shown in **Fig. 7**.

Flow Function

σ_1 and σ_c values have been determined at each consolidation level with the aid of yield loci by obtaining the draw of appropriate Mohr circles on the yield loci graphs. The variation of σ_1 with σ_c gives the flow function of the sugarbeet pulp pellets. The flow function obtained is illustrated in **Fig. 8**. According to the results in **Fig. 8**; the flow will be free for having a slope value of 0.0669 lower than 1 and ff_c is 14.5. For this reason, sugarbeet pulp pellets can be categorized as cohesive and free flowing material.

Analysis of Velocity Profile and Mass Flow Index (MFI)

The velocity profile predicted for each model in **Table 1** has been determined. **Fig. 9** compares the mean velocity profiles for all models in this study and for each of the three control volumes (CV1, CV2 and CV3) considered. Additionally MFI value has been determined for every mean velocity profile and is shown in **Fig. 9**. It is indicative of the flow pattern as well as the level of velocity variation at the height level was considered. Using MFI as a first indication of flow pattern, **Fig. 9** shows the MFI values, calculated from the mean velocity profiles against the associated control volumes, which represent the heights in the silo where the MFI values are evaluated. As a general trend, the value of MFI decreases (flow pattern approaches funnel flow) as the hopper becomes shallower or opening dimension is narrower. Furthermore, the MFI decreases with depth for all cases which indicates more uniform mass flow towards the upper region of the silo. From **Fig. 10**, since the MFI is always higher than 0.3 in CV1, no internal flow channel is predicted to develop at this height level in any of the models. Looking further at CV2 and CV3: if MFI > 0.3 in both control volumes, the flow pattern in the silo can be considered as mass flow. On the contrary, the flow can be considered as mixed flow when MFI < 0.3 in CV3 or in both CV2 and CV3. In the particular case of models M3 and M4, flow pattern should be characterized strictly as mixed flow since MFI < 0.3 for the volume CV3. However, both of M1 and M2 models MFI were above 0.3 in the vertical section which demonstrates a predominantly mass flow situation and have thus been classified as such.

Pressures Inside and Against Silo Walls

The results in this section are based on calculations of Janssen and Finite element method. **Fig. 11** shows the analytical analysis of horizontal and vertical pressures on silo wall at different heights for static conditions. Otherwise, the model silo design analysis was based on the maximum load conditions which are at pellets surges during silo fill-

ing and discharging times. Returning to one of the objectives of this article that is experimentally testing and validating, the theoretical design of the model silo, observation of surges in pressure during filling, pellets settling and discharging reveals that all the load cells registered surges in both wall and vertical pressures at the same time, even though readings were taken independently. The only difference between the two tests was the length of storage period (remained static inside the silo).

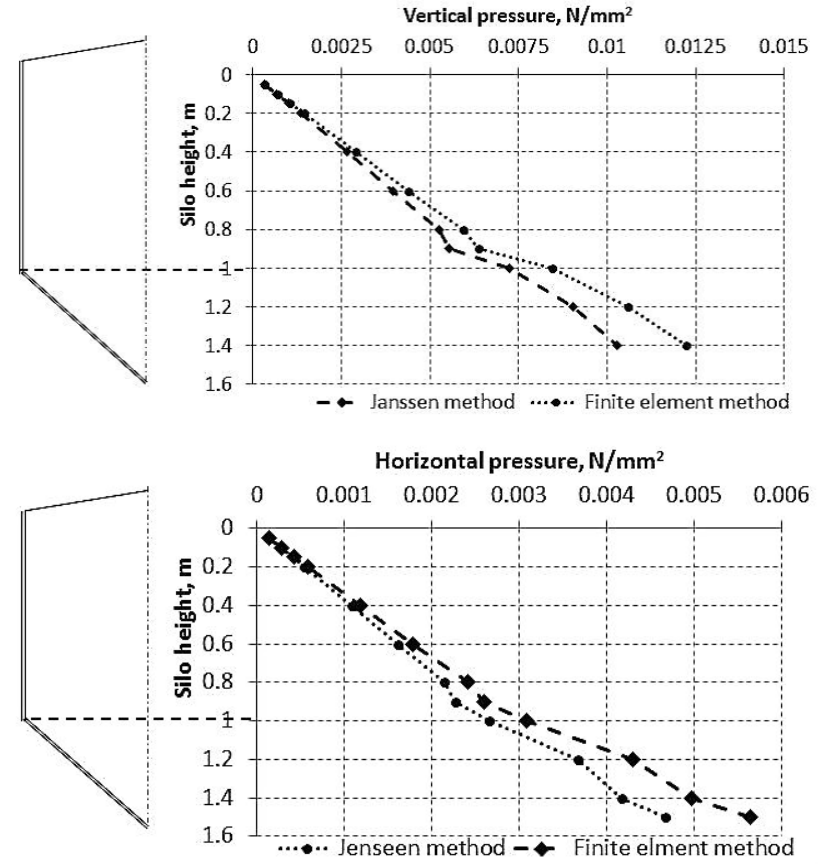

Fig. 11 Vertical pressure in the stored material and horizontal pressure against silo wall calculated by both of Janssen and Finite element methods

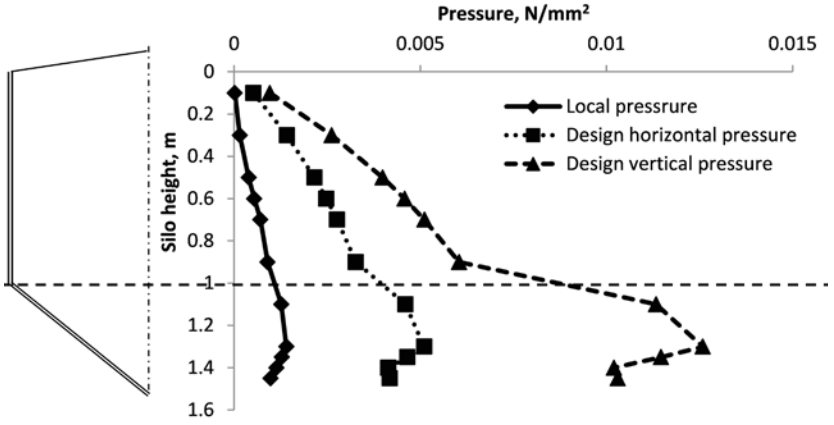

Fig. 12 Local and design horizontal and vertical pressure at each height of silo

Fig. 12 shows the local pressure which depends on eccentricity of discharge outlet. At each height point of silo wall, the highest value of local pressure occurs at a height of 1.2 m was due to the weight of solids in the hopper and the pressure derived from the cylinder (transition surcharge). The local pressure distribution supposed to be very peak at transition as well as design vertical and horizontal pressure. However in this model silo is not because of the hopper half angle (15°) is a little lower than the design half angle (22°) for mass-flow ensuring. Local pressure is applied to a partial area of silo wall 0.1 of silo diameter, so is much influenced by the variations in the straightness of the wall for compressive or tensile directions. These results clearly indicate that the hopper is not steep and rough for pellets discharging.

Vertical long-term design force per unit length of silo wall horizontal section at some depths from free surface is shown at **Fig. 13**. It is a measure for long term friction force between silo wall and stored materials. It can be inferred that the long term friction force increases tremendously at hopper section due to the loads come from the cylinder and hopper wall angle that is affect the vertical and horizontal components of forces and consequently the long term friction force.

The values obtained for normal wall pressure and design normal wall pressure of the stored material at the hopper as can be seen in the **Fig. 14**, design wall normal pressure of the stored material at hopper increased over hopper height, and the same was for normal pressure of hopper wall until height of 1.3 m. The opposite was the case for normal wall pressure after height of 1.3 m which decreased. In other words, the normal wall pressure peaks at this point of silo height, increasing other stress parameters such as circumferential wall stress,

bending stress and tensile stress in both circumferential and generator directions, **Fig. 14**. The circumferential wall stress was analyzed under different wall thicknesses at of 0.1, 0.2 and 0.5 mm, **Fig. 14A**. The optimum thickness can be selected for buckling evade is 0.5 mm, so the other stress calculation was based on 0.5 mm thickness. **Fig. 14B** shows the normal pressure on hopper wall which has a linear correlation at storage conditions that indicates the normal pressure increases as hopper depth increased. However at discharging conditions or design conditions, the normal wall pressure peaks at 1.3 m silo height. It's observed that the normal pressure of the cylindrical wall part is omitted due to the normal pressure is concede as horizontal pressure, for that reason the normal pressure is the horizontal pressure.

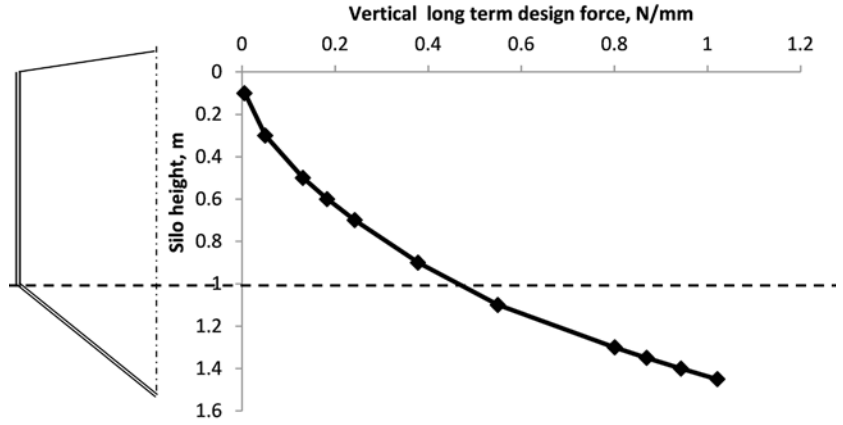

Fig. 13 Vertical long-term design force per unit length of silo wall horizontal section at each height from free surface

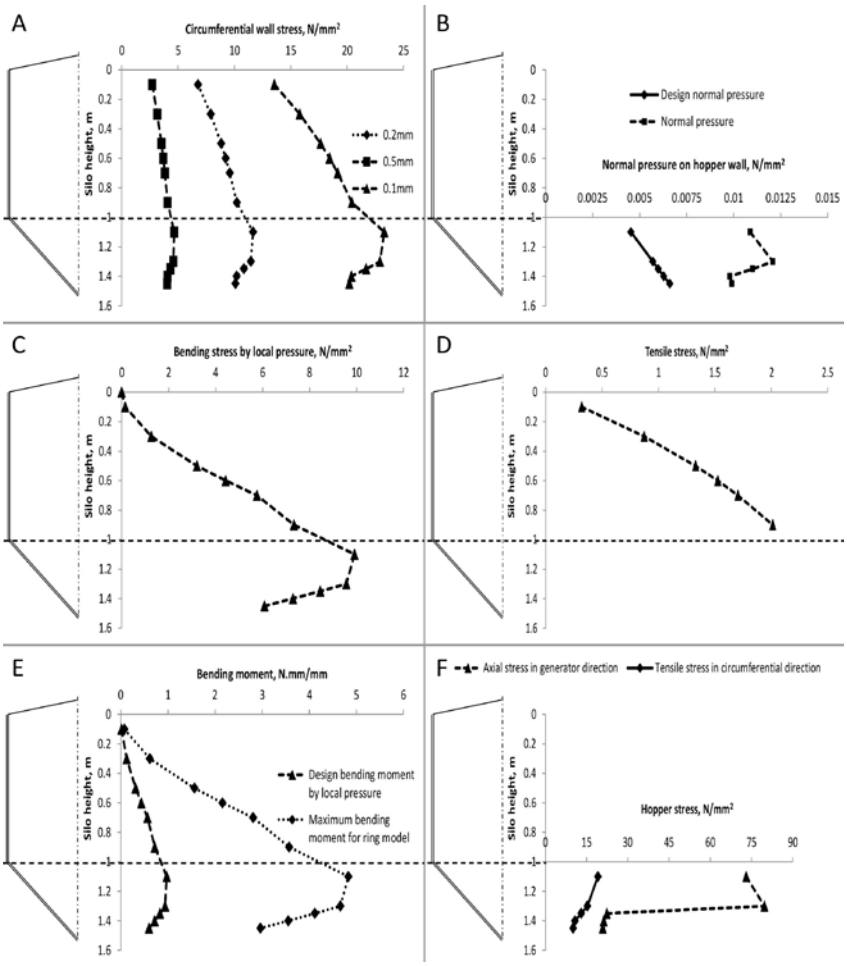

Fig. 14 Wall stress evaluation at each height of sugarbeet pulp pellets silo

Fig. 14E shows two different results of bending moments, the first is calculated based on bending moment per unit width of the ring model and the other one is based on local pressure (0.1 of silo wall diameter). Bending moments, based on ring model, show values higher than for local pressure, so the values of ring model is considered as a maximum conditions for design calculations. **Fig. 14C** shows the bending stress by local pressure which records the maximum value at 10.2 N/mm^2 at silo height of 1.1 m. **Fig. 14D** shows the tensile stress at outer surface of cylinder section of the silo which merely equal the compression stress at the opposite surface of cylinder (inner side), the tensile stress increases proportionally with silo height to be 2.014 N/mm^2 at 0.9 m height. At silo-hopper transition, the tensile stress is divided into two types of stresses as shown in **Fig. 14F**, axial stress in generator direction and tensile stress in circumferential direction. The axial stress in generator direction has two maximum values of 73.1 and 79.7N/mm^2 at 1.1 and 1.3 m of silo height. Downward the axial stress in generator direction decreases tremendously to be around 22.3 to 20.9 N/mm^2. Whereas the tensile stress in circumferential direction is decreased from 19.13 to 10.08 N/mm^2. **Fig. 15** also shows the coherence among the results obtained during storing, filling and discharging. Normal wall pressures reached

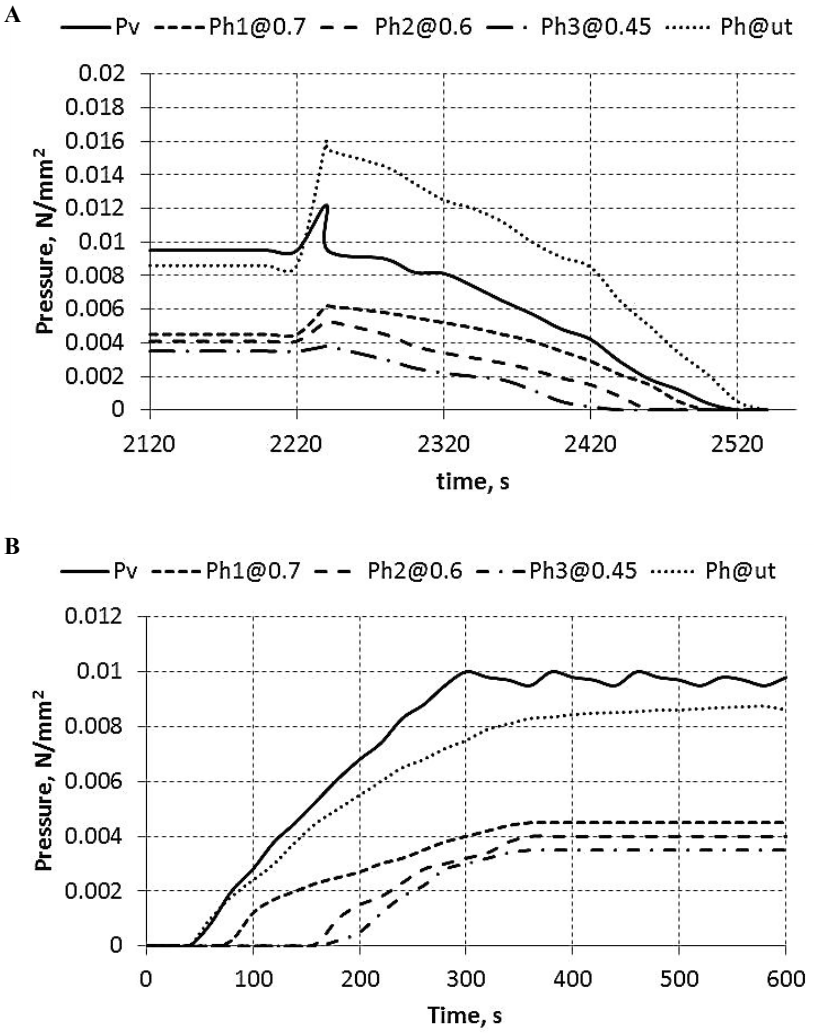

Fig. 15 Horizontal wall pressure and vertical stresses in the stored material at transition for pre, during and post discharging and filling processes; A- discharging and B-filling.

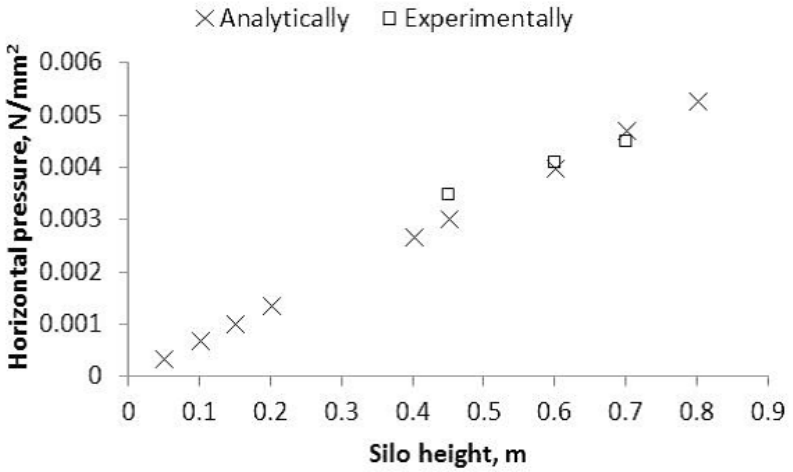

Fig. 16 Comparison between horizontal wall pressures obtained by the experiments and by using the analytical method

their highest values at discharge process beginning, at the hopper wall at the level of the silo-hopper transition, in accordance with European standards (EN 1991-4, 2006) and in agreement with international tests on real silos (Härtl *et al.*, 2008; Ramirez *et al.*, 2010 and Ruiz *et al.*, 2012). Thus, **Fig. 15B** shows how, as hopper filling approached completion, readings began at Ph@ut, immediately followed by the three vertical load cells (S1, S2 and S3), from which vertical pressure (Pv) of the stored material at the silo-hopper transition was obtained. From this point onwards, hopper filling was completed and cylinder filling began. The progress of filling is clearly visible since the readings given by the cylinder wall load cells (Ph1@0.7, Ph2@0.6 and Ph3@0.45) began to rise as the pellets approached their level. Once filling was completed, the phenomenon of pellets settling began. The time interval between each surge became longer, a phenomenon of pellets settling continued to occur throughout the static phase of the test. Coherence among the results obtained during discharge can also be observed in **Fig. 15**. Thus, as the cylinder was emptied, pressure readings at the (Ph1@0.7, Ph2@0.6 and Ph3@0.45) cells, located at different heights of the cylinder wall, approached zero. Cylinder discharge was completed at Pv and (Ph1@0.7, Ph2@0.6, Ph3@0.45 and Ph@ut) readings equaled zero at the point when hopper discharge began. Cell Ph@ut, located in the hopper, continued to provide readings until the material fell below the level of the cell. Furthermore, for the same reason as in the case of filling, from the results obtained it can be deduced that discharge occurred at a constant speed. For the static conditions, at the end of filling and just before starting discharge, vertical pressure of the stored material at the silo-hopper transition increased over storage period, and the same

trend was true for normal hopper wall pressure. In contrast, the opposite was the case for normal cylinder wall pressure, which decreased over time. In other words, the cylinder walls released some of their load, increasing the weight borne by the hopper.

Coherence among the results obtained during storage can be observed in **Fig. 16**. So the average pressure readings at the (Ph1@0.7, Ph2@0.6 and Ph3@0.45) load cells, located at different heights of the cylinder wall (0.45, 0.6 and 0.7m) have a maximum difference of 0.0005 N/mm^2 during the two tests (two different storage periods).

Conclusions

For appropriate silo design to store any agricultural product, the engineering properties should be studied. Sugarbeet pulp pellets have a bulk density of 672.67 kg m^{-3}, internal friction angle of 30° and silo wall-pellets friction angle of 20°. Sugarbeet pulp pellets show different cohesion values and pre-shear normal stresses, increase from 0.412 to 0.782 kPa and from 4.12 to 31.80 kPa, respectively as moisture content increases from 4.8 to 6.2% wb. The unconfined yield strength and the consolidation stress are 2.24 and 275 kPa, respectively. Finally the flow function obtained from the slope of the line acquired from the effect of consolidation stress on unconfined yield strength is 0.0669 (<1) as well as the flow index is 14.5. Therefore, sugarbeet pulp pellets can be classified as cohesive and free flowing material. For discharging behavior analysis, the first two models M1 and M2 of hopper half angles 10° and 20° and discharging opening dimensions 0.17 and 0.13 m represent mass flow pattern at each height. Where the other two models M3 and M4 of hopper half angles 40° and 60°and discharging opening dimensions 0.07 and 0.03 m show flow pattern approaches funnel flow. Horizontal and vertical pressures on silo wall at different heights for storage conditions were analyzed analytically using Janssen and Finite element methods and experimentally using load cells to verify the analytical methods. The silo design analysis was based on maximum values of pressures which achieved at discharging or filling the silo. Stresses distribution analysis on silo wall was expressed by the following parameters:

1) Local pressure, the maximum values obtained at hopper section ranged from 0.001 to 0.0014 N/mm^2.
2) Design horizontal pressure and vertical pressure, the same behavior of local pressure maximum values can achieved at hopper part ranged from 0.0041 to 0.0051 N/mm^2 and ranged from 0.0102 to 0.0126 N/mm^2 for design horizontal and vertical pressure, respectively.
3) Vertical long term design force per unit length of silo wall which is a measure of friction force between silo wall and the stored pellets, which were at the hopper of 85.7% higher than those obtained by cylindrical section.
4) Normal pressure of hopper wall which peaks at height of 1.3 m increasing other stress parameters such as circumferential wall stress, bending stress and tensile stress in both circumferential and generator directions. Circumferential wall stress for hopper wall shows the optimum wall thickness is 0.5mm for buckling evade at filling or discharging conditions.
5) Bending moment based on ring model show values higher than for those calculated based on local pressure, bending stress calculated based on local pressure records the maximum value of 10.2 N/mm^2 at height of 1.1 m.
6) Tensile stress increases proportionally with silo height for cylinder section to be 2.014 N/mm^2 at 0.9m height.
7) At hopper section, the axial stress in generator direction and tensile stress in circumferential direction. Axial stress in generator direction has a maximum value of 79.7 N/mm^2 at 1.3m in height, and tensile stress in circumferential direction decreases from 19.13 to 10.08 N/mm^2 at silo height from 1.1 to 1.45 m.

The construction of a model silo has presented in this article to obtain the following parameters:

- Lateral pressure on the vertical silo wall.
- Pressure at areas close to the silo-hopper transition in silos with hoppers.
- Vertical pressure at the stored solid at transition.

During filling and when the pellets stored inside the silo is static, the highest horizontal wall pressures, cylindrical part, occurred just at the end of filling. In contrast, the opposite was true for the hopper wall, and increased over storage time. The highest pressures inside the silo occurred during the first seconds of discharge. The highest normal wall pressures occurred at the hopper wall, at the silo-hopper transition. This was also where the highest normal wall pressures were produced in the cylinder, although these pressures were considerably lower than those reached in the hopper. Under static conditions, the stored pellets undergo a process of settling. During this process, the cylinder walls released pressure, increasing the normal wall pressure of the hopper and the vertical pressure of the stored material at the silo-hopper transition. This phenomenon occurred in surges over increasingly longer time intervals between filling and discharging processes.

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Promoting Agricultural Productivity in Nigeria – The Case of the Agricultural Credit Guarantee Scheme Fund (ACGSF): 1981 to 2014

by
M. A. Olaitan
maolaitan@cbn.gov.ng

B. O. Ogunlaja
boogunlaja@cbn.gov.ng

L. Juma
ljuma@cbn.gov.ng

M. A. Olasupo
maolasupo@cbn.gov.ng

J. Yusuf
jyusuf@cbn.gov.ng

Development Finance Department, Central Bank of Nigeria (CBN), Abuja
NIGERIA.

O. A. Oyelade
Farm Power and Machinery Department
National Centre for Agricultural Mechanization (NCAM), Ilorin
NIGERIA
yemibamigbedjdoyelade@gmail.com

Abstract

The Nigerian agriculture landscape is dominated with sparsely scattered small holder farmers who have huge potential for high productivity. The ACGS Fund was established to enhance the purveyance of credit to this critical but high risk segment of the agriculture workforce. This paper reviewed the activities of the ACGS Fund and its contribution to increasing agricultural productivity in Nigeria. A one-way ANOVA without replication was used to compare the means between and within the factors being analysed. The one-way ANOVA was used in establishing increase in uptake of loans within a given category of borrower and between borrower categories; and within a given loan limit and between loan limits. In addition, a two-way ANOVA with replication was used to study the effects of period (year group) and purpose of loan, loan size and purpose of loan, and year group and loan size on the disbursement of ACGS loan. It was established in the findings of this paper that year group, purpose of loan and loan size had significant effect on the disbursement of ACGS loan. More so, the ACGS Fund assisted small holder farmers in accessing small loans for their farm business through the 75% guarantee. The paper also provided empirical evidence to show that the productivity of farmers under the Scheme was improved thereby reducing poverty level and creating jobs.

Keywords: farmers, guarantee, credit, agricultural, purpose, size

Introduction

Nigeria‘s agricultural endowment is enormous, ranging from diverse climate from the tropical areas in the south to the arid zone in the north with also a very rich vegetation a viable haven for crop and livestock production (Kemisola *et al.*, 2004). Nigeria also has a land area of 98.3 million hectares out of which 71.2 million hectares representing 72.4% are said to be cultivable. The agricultural sector of Nigeria employs 70% of the labour force. These potentials no doubt present agriculture as a strategic platform to addressing Nigeria’s challenges of economic growth, wealth creation, unemployment and food security. However, despite her rich potential for agricultural production, the sector’s productivity is yet to be optimally utilized.

Agricultural Productivity in Nigeria

It was observed that less than 50% of Nigeria's cultivable agricultural land translating to about 30.7 million hectares is yet to be cultivated. Smallholder and traditional farmers dominate the agricultural space, with lack of access to finance; they

have been forced to use rudimentary production techniques which resulted in low yields (Manyong *et al.*, 2005). To increase agricultural productivity in Nigeria, numerous policies and programmes were introduced by Government which has not translated to significant change in productivity. The country continues to be one of the major importers of food due to a number of constraints inhibiting the performance of the sector. One the major factor is the lack of sustainable access to finance. This was collaborated by Olaitan (2006) in a study which identified shortage of primary production credit as one of the major causes of declining agricultural production. It attributed the shortage to commercial banks' reluctance to provide credit for real sector activities, especially agricultural production which was largely due to inherent risks associated with agricultural production; urban/semi urban based nature of operations of the commercial banks; high cost of administration of agricultural loans; and inability of farmers to provide the necessary collateral. It was on this premise, that the Agricultural Credit Guarantee Scheme Fund (ACGSF) was established by the Central Bank of Nigeria to encourage banks be favourably disposed to lending to agriculture by de-risking the sector.

The Need for Intervention in Agriculture to Boost Productivity

The Central Bank of Nigeria (CBN) intervention in the agriculture sector started in the 1960s concurrently with the achievement of its core mandate of price stability. Accordingly, its developmental role has been actively targeted at critical sectors of the economy such as the agricultural value chain. Between 1962 and 1967, the CBN financed the activities of the Regional Marketing Boards, under the Commercial Bill Finance Scheme. It established the Bank of Agriculture in 1973; set up the Agricultural Credit Guarantee Scheme in 1978 and Export Credit Guarantee in 1987. The Bank also initiated the Agricultural Credit Support Facility in 2008; Commercial Agricultural Credit Scheme (CACS) in 2009; and Nigeria Incentive-Based Risk Sharing System for Agricultural Lending (NIRSAL) in 2011.

Objectives

This paper examined the contribution of the Agricultural Credit Scheme Fund (ACGSF) in promoting agricultural productivity in Nigeria. In specific terms, the paper:

a. Reviewed the concept of credit guarantees and how it provides credit enhancement to boost agricultural activities.
b. Provided an overview of the ACGS Fund, its establishment, operational framework (how the guarantee is made available to beneficiaries), innovations and claims settlement regime.
c. Examined disbursement under the ACGSF to ascertain if there was any significant difference in the uptake of loans across categories of borrower, sizes of loans, purpose of the loans over the period of existence of the Scheme.
d. Examined the impact of the Scheme on the agricultural productivity, job and wealth creation.

Conceptual Note on Credit Guarantees

Professionals had advocated that credit guarantees will address difficulties facing individuals, households, farms and other small firms that wish to borrow from banks and other formal sources. Nitsch and Kramer (2010) reported that in any credit guarantee system the basic loan relationship between the borrower and the bank is extended through a third party, the guarantor. They further explained that though the financing (provision of funds or liquidity) remains with the bank, the credit (the trust, confidence and risk of default) is shared between the bank and the guarantor.

Gudger (1998), x-rayed several credit guarantee systems worldwide and analysed the various guarantee schemes on continental basis. He reported that most credit guarantee scheme In Africa were established with donor funds, Government funding and operating on relatively small scale. However, they have been plagued by poor implementation and performance such as high costs and defaults, which have led to the untimely termination of most of the schemes. He observed that it is only the Agricultural Credit Guarantee Scheme in Nigeria of all the schemes in Africa that offered sufficient data to permit close assessment as most other African guarantee systems were relatively newly established.

Researchers have also examined the activities of the ACGS in terms of its operations and extent of credit delivery to promoting agricultural productivity in Nigeria. Okon and Nkang (2009) in their time series analysis of the ACGS recommended that the managers of the scheme should step up the pursuit of repayment of loans and adopt automation of the processing and approval of guarantees and default claims.

Nwosu *et al*. (2010) examined "The Agricultural Credit Guarantee Scheme: Its Roles, Problems and Prospects in Nigeria's Quest for Agricultural Development". The authors concluded that since credit is needed for enhanced productivity and agricultural development, the three tiers of government in Nigeria should give the scheme the necessary support and publicity so that farmers (particularly small holder farmers) can benefit from its services. This they posited will go a long way in ameliorating the seemingly dismal output of our farmers.

Adetiloye (2012) in the study "Agricultural Financing in Nigeria:

An Assessment of the Agricultural Credit Guarantee Scheme Fund (ACGSF) for Food Security in Nigeria (1978 - 2006)" examined the provision of credit to the sector and the performance of the ACGSF. It was observed that settlement of claims under the ACGSF was negatively significant. It recommended further enlightenment campaigns to bring the youth into agriculture.

Overview of the Agricultural Credit Guarantee Scheme

Establishment of the ACGS Fund

According to (http://www.cenbank.org/out/Publications/guidelines/dfd/1990/guidelines-acgsf.pdf), the Agricultural Credit Guarantee Scheme Fund (ACGSF) was established by Decree No. 20 of 1977 and became operational in April 1978. The initial share capital of the Fund was ₦100 million in the ratio of 60:40 between the Federal Government and the Central Bank of Nigeria, respectively. In March, 2001, the capital base of the Fund was increased to ₦3 billion. The total resource available to the Fund was ₦7.135 billion as at December 2015 as a result of investments in Nigeria Treasury Bills (TB).

The Fund guarantees credit facilities extended to famers by banks up to 75% of the amount in default net of the security realized. The Fund is managed by the Central Bank of Nigeria (CBN), which acts as the Managing Agent for the administration and handling of the day-to-day operations of the Scheme through its Development Finance Department. It also has a Board that provides policy direction.

The objective of the Scheme is to encourage commercial banks to lend to those engaged in agriculture by providing guarantee for loans granted by such banks for crop and livestock production, processing and marketing. The specific objective of the Scheme has been the stimulation of credit for agricultural production for both domestic consumption and export, it is particularly focussed on ensuring that banks are favourably disposed to financing the sector.

Operational Framework of the ACGS

Enterprise and categories of borrowers under ACGS

The activities covered under the Scheme are the establishment or management of plantation for the production of rubber, oil palm, cocoa, coffee, tea and similar crops. Also the production of cereal crops, tubers, fruits of all kinds, cotton, beans, groundnuts, sheanuts, beniseed, vegetables, pine-apples, bananas and plantains; animal husbandry (poultry, piggery, cattle rearing) and fish farming and fish capture; processing (where it is integrated with at least 50% of farm output e.g. cassava to gari, oil palm fruit to oil and kernel, groundnut to groundnut oil, etc), and farm machinery and hire services are also covered by the Scheme.

How to participate under the scheme

The ACGS as earlier mentioned is targeted at providing guarantees to `commercial banks' for their exposure to farmers. Farmers that accessed loans below ₦20,000.00 are not required to provide security to their banks. The collateral requirement for loans above ₦20,000.00 may include a charge on land or a right to farm, or a charge on assets on the land including fixed assets, crops or livestock; a charge on the movable property of the borrower; a life assurance policy, a promissory note, stocks and shares, or other negotiable security; a personal guarantee; and any other security acceptable to the bank.

To avail the guarantee, commercial banks will send the applications of farmers on the Scheme's prescribed application forms. The applications are completed in triplicate, one copy of which will be stamped by the commercial bank concerned and forwarded immediately to the nearest office of the Central Bank in the State in which the bank is situated. It is expected that the application should reach the CBN within 60 days and be treated with the same degree of due diligence with which they would normally treat other applications for loans received in the normal course of their banking business.

Default and Claim Settlement Under the ACGS Fund

The ACGS stipulates that temporary default on the instalment repayment of a guaranteed loan need not be reported to the Fund if the bank has no intention, merely on the basis of such a default, either to discontinue the facility or to call up the loan. If, however, the bank does not succeed in its efforts to regularize the account and calls up the loan, it should serve the Fund with a "Notice of Default" by completing the prescribed format in duplicate copies and correspondences between the commercial bank and the customer since the default was noticed are to be attached in duplicate.

After giving "Notice of Default" in the prescribed manner, the commercial bank make further efforts to recover the amount in default from the borrower or his/her sureties, if any, and may, for that purpose, dispose of any security obtained in respect of the loan. If any balance remains outstanding after the above step has been taken, or where the recovery of any amount outstanding is impracticable, the commercial bank may apply to the Fund for payment in accordance with terms of the guarantee. If within six months from the date of receipt of "Notice of Default" no "Guarantee Claim" is received by the Fund, it will be presumed that the bank has recovered its loan and the Fund shall be deemed to have been discharged from its liability under the guaran-

tee.

Claim under the guarantee are to be submitted by the commercial banks. If the claim is in order, the amount payable under the guarantee will be remitted to the Head Office of the commercial bank. Upon a payment being made as provided for above, the Fund shall be deemed to have been discharged of all its liabilities under the Guarantee. The amount received from the Fund in settlement of a claim must not be credited to the account of the borrower who will remain liable to the bank for his total indebtedness. After payment of the Guarantee claim, the bank continues to pursue recovery. The balance of a loan outstanding in respect of which a claim has been paid by the Fund must not be written off by the bank without the approval by the Fund.

Innovations Under the ACGS Fund

In order to improve access to agricultural loans under the ACGS, the CBN introduced a number of innovations to boost commercial banks' participation. The innovations are to improve repayment of agricultural credit, mitigate risk and reduce the cost of lending to the sector. Some of them are the following:

Interest drawback programme (IDP)

The IDP was introduced in January, 2003 with a capital base of ₦2.0 billion subscribed to by the Federal Government (60%) and Central Bank of Nigeria (40%). The main objective of the IDP is to provide interest rebates to farmers that borrowed under the ACGS to reduce the cost of borrowing and the burden of high interest rate. This removed the complications of re-introducing a dual interest rate regime which would contradict the deregulation policy of the Government. Farmers who borrowed from commercial banks under the ACGS will benefit from interest rebate of 40% on their loans provided they repaid the loans as scheduled.

Trust fund model (TFM)

The Trust Fund Model (TFM) was conceived by the Central Bank of Nigeria in 2001 to reduce the risk exposure of banks in agricultural lending to uncollateralized farmers. It involves intermediation by any willing counterparty by way of placing funds in the commercial banks of its choice as cash security for loans to farmers, particularly farmers' groups and cooperatives. The counterparties may include Governments (State or Local), Non-Governmental Organisations NGOs, Companies and Philanthropists, etc. A Memorandum of Understanding (MOU) is signed where counterparty signifies its intention to partake in the TFM intervention initiative. A tri-partite arrangement comprising the Central Bank of Nigeria, the counterparty and the lending bank is put in place and include the roles and responsibilities of each party.

The TFM was introduced to reinforce the confidence of banks in granting credit facilities to farmers. The counterparty (NGOs, Government, Companies etc.) is required to deposit about 25% of the loan amount, and while the clients (farmers) will also save up to 25% of the same loan amount; making a total deposit of 50%. The ACGS guarantees 75% of the remaining 50% of the loan amount to be provided by the lending banks, which reduces their risk exposure to 12.5%. This was to encourage banks to further lend to the farmers, particularly those that cannot provide collateral security for their loans.

Self help group linkage banking programme (SHG-LBP)

The SHGs Linkage Banking Programme was launched under the Agricultural Credit Guarantee Scheme (ACGS) in 1999. The Linkage Banking Programme was introduced to mobilise savings among farmers with the objective of improving rural and grassroots financial intermediation. The model was first advocated by the Africa Regional Agricultural and Rural Credit Association (AFRACA) in 1987 and was promoted as a regional strategy for savings mobilization to address effective and sustainable delivery of financial services to rural dwellers and micro entrepreneurs. Farmers are encouraged to come together in groups of between 5 to 10, save periodically in a commercial bank of their choice which will enable them access credit facilities. The savings mobilized will be used as collateral for bank credit. The members are held together by common economic goals.

Performance of the ACGS Fund

The total loans guaranteed from inception in 1978 to December, 2014 was 929,472 valued ₦88.905 billion. The intervention of the Central Bank of Nigeria in the agriculture sector has stimulated the creation of jobs both directly and indirectly. The ACGS intervention has led to the creation of a total of more than 929,472 direct jobs and 3.4 million indirect jobs.

The ACGS has also promoted financial inclusion by providing access to finance to smallholder farmers numbering over 929,472 farm families as at December 2014. These are very crucial economic agents, who otherwise would not have had access to finance.

Methodology and Data Analysis

Data Sources and Methods

The study used secondary data on ACGS activities, various publications of the Central Bank of Nigeria, including the Statistical Bulletin and various ACGS Annual Reports and Financial Statements. A simple to complex descriptive statistics were used to analyse the ACGS secondary data of 34 years (1981-2014) period. The data range was limited to this period due to inadequate

Table 1 ACGS loans by categories of borrowers (N'000)

Year	Individual	Informal Group	Co-operative	Company	Grand Total
1981	17,813.40	-	796.10	17,032.90	35,642.40
1982	16,117.70	-	474.00	15,172.20	31,763.90
1983	14,197.80	-	609.90	21,499.80	36,307.50
1984	9,853.90	-	377.00	14,424.00	24,654.90
1985	19,407.70	-	702.00	24,133.90	44,243.60
1986	25,643.30	-	1,099.10	41,675.00	68,417.40
1987	54,897.20	-	4,379.00	42,876.30	102,152.50
1988	80,078.90	-	4,166.30	34,365.80	118,611.00
1989	104,329.00	-	4,677.80	20,293.50	129,300.30
1990	86,290.25	-	5,938.80	6,353.27	98,582.32
1991	69,995.32	-	5,343.47	6,841.90	82,180.69
1992	75,616.53	-	6,864.42	5,629.42	88,110.37
1993	68,318.82	-	9,056.58	3,542.56	80,917.96
1994	86,529.06	-	9,008.13	7,740.90	103,278.09
1995	132,896.81	-	19,303.01	12,108.80	164,308.62
1996	179,985.20	-	34,456.13	11,262.44	225,703.77
1997	184,850.84	7,523.21	34,409.68	15,470.50	242,254.23
1998	190,475.06	1,706.52	8,968.00	14,740.14	215,889.72
1999	193,673.71	1,352.21	42,363.28	8,912.95	246,302.15
2000	381,130.24	11,750.60	26,955.26	5,102.31	424,938.41
2001	855,807.49	-	117.56	587.82	856,512.87
2002	1,205,716.05	12,454.81	16,658.93	1,469.56	1,236,299.35
2003	1,300,803.16	36,179.39	19,080.77	12,932.13	1,368,995.45
2004	2,371,687.09	24,900.22	37,173.99	15,988.81	2,449,750.11
2005	3,490,612.34	23,555.87	45,306.30	22,417.25	3,581,891.76
2006	4,684,834.07	97,180.23	202,168.89	27,674.75	5,011,857.94
2007	4,873,543.26	268,282.85	32,625.76	28,803.37	5,203,255.24
2008	7,238,803.27	340,019.71	194,540.34	128,253.97	7,901,617.29
2009	8,811,820.04	151,275.32	690,095.92	162,891.90	9,816,083.18
2010	7,202,578.78	42,285.54	243,999.37	74,835.65	7,563,699.34
2011	9,161,251.34	375,855.05	298,200.69	121,546.74	9,956,853.82
2012	8,919,787.28	27,347.72	261,203.63	276,701.23	9,485,039.86
2013	8,475,346.08	177,388.39	364,294.29	192,148.36	9,209,177.12
2014	11,785,905.97	302,012.19	457,036.36	155,172.70	12,700,127.22
	82,370,596.96	1,901,069.83	3,082,450.76	1,550,602.83	88,904,720.38

Table 2 Summary table for categories of borrowers

Groups	Count	Sum	Average	Variance
Individual	34	82370596.96	2422664.62	12,858,842,054,447.00
Informal Group	34	1901069.83	55913.82	9,993,714,270.04
Co-operative	34	3082450.76	90660.32	25,593,806,967.30
Company	34	1550602.83	45605.97	4,263,473,605.37

data on ACGSF activities between 1978 and 1980. In addition, the data were cleaned to achieve consistency across categories of borrowers, loan size limit, and purpose of loan.

Statistical Analysis and Results

Descriptive statistics and ANOVA were used to draw inferences. A one-way ANOVA without replication was used to compare the means between and within the factors being analysed. The one-way ANOVA is very relevant in this research as it will assist in establishing increase in uptake of loans within a given category of borrower and betweern borrower categories; and within a given loan limit and between loan limits. In addition, a two-way ANOVA with replication was used to analyse the mean value of loans by purpose, period (year group) and loan size. To provide the basis for replication and also achieve the desired result, the following factors were considered in the analysis: the year group, purpose for which the loans were disbursed and size of the loans.

Analysis of categories of borrowers

The ACGS loans across categories of borrowers (individuals, informal groups, cooperatives and companies) under the Scheme (data in **Table 1**) were analysed using one-way ANOVA at 5% probability level. The average mean value of loans was compared within and between categories of borrower for a period of 34 years (1981-2014). **Table 2** presents the summary table for the categories of borrowers.

The F-test statistic was used to test for the overall statistical significance of the ANOVA results at 95% confidence interval and the joint

Table 3 ANOVA table for categories of borrowers

SV	SS	df	MS	F	P-value	F crit
Between Groups	141,894,789,864,942.10	3	47,298,263,288,314.02	14.6658	0.0000001	2.673
Within Groups	425,710,018,633,100.20	132	3,225,075,898,735.61			
Total	567,604,808,498,042.30	135				

SV = Source of Variation, SS = Sums of Squares, df = Degree of Freedom, MS = Means of Squares

hypothesis was given by:

$H_0 : \mu_1 = \mu_2 = ... = \mu_S$ *and* $H_0 : \mu_1 = \mu_2 = ... = \mu_t$

Where

H_0 : No significant difference in the mean values of loans across categories of borrowers

H_1 : No significant difference in the mean values of loans within categories of borrowers

The ANOVA result is presented in **Table 3**. The analysis of the mean values of loans between the four (4) types of beneficiaries (Individual, Informal Groups, Cooperatives and Companies) given by the one-way ANOVA ($F_{05, (3,132)} = 2.6732$, $P_{\text{-value}} = 0.0000001$, $F_{stat} = 14.6658$) as contained in **Table 3** provided a basis for the rejection of the joint hypothesis. This implied that the mean values of the loan amount were statistically different between and within categories of borrowers

Table 4 ACGS LOANS BY SIZE (₦'000)

Year	5,000 & Below	5,000–20,000	20,001–50,000	50,001–100,000	Above 100,000	TOTAL
1981	4,345.60	2,603.30	8,909.20	968.00	18,816.30	35,642.40
1982	9,931.60	1,904.30	6,678.80	411.50	12,837.70	31,763.90
1983	2,165.80	2,666.50	8,456.00	510.00	22,509.20	36,307.50
1984	3,452.10	2,792.70	5,242.90	729.40	12,437.80	24,654.90
1985	5,955.50	5,142.90	9,251.80	1,487.40	22,406.00	44,243.60
1986	10,030.60	6,778.30	10,476.00	2,976.70	38,155.80	68,417.40
1987	40,261.30	7,378.50	9,063.00	3,953.50	41,496.20	102,152.50
1988	65,352.90	10,247.90	8,049.00	3,843.10	31,118.10	118,611.00
1989	88,095.20	10,662.90	6,735.60	5,787.80	18,018.80	129,300.30
1990	74,374.72	6,283.00	6,173.71	5,459.27	6,291.61	98,582.31
1991	56,607.28	7,091.42	5,197.33	5,990.34	7,294.30	82,180.67
1992	62,269.73	7,834.09	5,985.64	5,908.07	6,112.85	88,110.38
1993	52,330.77	9,355.44	6,125.56	8,822.57	4,283.62	80,917.96
1994	56,428.02	15,610.82	8,535.91	13,077.76	9,625.58	103,278.09
1995	65,239.18	31,671.64	17,150.99	26,882.07	23,364.73	164,308.61
1996	57,818.16	64,197.35	23,008.72	51,368.21	29,311.34	225,703.78
1997	41,315.14	87,027.31	29,795.47	53,055.91	31,060.40	242,254.23
1998	24,840.55	92,382.38	21,433.71	53,246.68	23,986.39	215,889.71
1999	13,261.23	112,801.29	37,241.11	50,922.91	32,075.60	246,302.14
2000	1,942.17	172,219.72	136,541.63	49,938.70	64,296.18	424,938.40
2001	3,347.54	159,073.16	361,041.12	202,217.91	130,833.15	856,512.88
2002	853.87	141,357.79	493,711.70	380,783.78	219,592.22	1,236,299.36
2003	1,590.06	203,011.47	350,831.21	463,095.00	350,467.70	1,368,995.44
2004	1,745.84	203,987.02	557,645.55	741,873.81	944,497.90	2,449,750.12
2005	403.01	274,990.04	697,826.63	852,063.52	1,756,608.56	3,581,891.76
2006	864.69	197,218.15	1,047,856.99	1,257,105.85	2,508,812.28	5,011,857.96
2007	148.13	66,850.87	754,949.27	1,302,921.99	3,078,384.98	5,203,255.24
2008	981.67	38,875.15	1,080,698.73	1,227,979.41	5,553,082.33	7,901,617.29
2009	161.66	106,292.77	806,983.16	1,156,296.61	7,746,348.97	9,816,083.17
2010	118.24	66,671.42	629,320.77	1,084,397.46	5,783,192.82	7,563,700.71
2011	229.63	103,626.61	614,097.62	1,246,764.05	7,992,137.80	9,956,855.71
2012	25,581.02	96,070.46	412,768.52	858,157.14	8,092,464.66	9,485,041.81
2013	488.58	72,417.18	680,365.83	1,429,868.86	7,026,038.36	9,209,178.81
2014	173.93	140,439.12	578,805.87	1,556,647.96	10,424,053.47	12,700,120.35
	772,705.42	2,527,532.97	9,436,955.05	14,105,513.24	62,062,013.70	88,904,720.38

Table 5 Summary table for loan size

Groups	Count	Sum	Average	Variance
5,000 & Below	34	772,705.42	22,726.63	778,029,224.96
5,000–20,000	34	2,527,532.97	74,339.21	5,632,090,097.00
20,001–50,000	34	9,436,955.05	277,557.50	119,011,426,372.08
50,001–100,000	34	14,105,513.24	414,868.04	299,898,746,871.14
Above 100,000	34	62,062,013.47	1,825,353.34	9,646,734,190,636.75

Table 6 ANOVA Table for loan size

SV	SS	df	MS	F	P-value	F crit
Between Groups	75,467,376,596,761.00	4	18,866,844,149,190.25	9.3659	0.0000	2.4264
Within Groups	332,377,797,945,664.00	165	2,014,410,896,640.39			
Total	407,845,174,542,425.00	169				

SV = Source of Variation, SS = Sums of Squares, df = Degree of Freedom, MS = Means of Squares

at 95% confidence interval.

Analysis of mean values of loan sizes

The values of ACGS loans across sizes (₦5,000 and below; ₦5,001-₦20,000; ₦20,001-₦50,000; ₦50,001-₦100,000; and Above ₦100,000) as presented in **Table 4**, were analysed using a one-way ANOVA at 5% probability level. The average values were compared within and between loan sizes for the period 1981-2014. **Table 5** presents the summary table for the loan size. The F-test statistic was used to test for the overall statistical significance of each of the ANOVA results at 95% confidence interval. The joint hypothesis was given:

$H_0 : \mu_1 = \mu_2 = ... = \mu_x$ *and* $H_0 : \mu_1 = \mu_2 = ... = \mu_y$

Where

H_0 : No significant difference in mean amount of loans between loan sizes

H_1 : No significant difference in the mean amount of loans within a loan size

The ANOVA result is presented in **Table 6**. The analysis of the mean of values of loans between the five (5) groups of loan sizes for the 34 years' period using the one-way ANOVA ($F05, (4,165) = 2.4264$, P-value = 0.00000003, $F_{stat} = 9.3659$) as shown in **Table 6** showed we reject the joint hypothesis. This implied that there was statistically significant difference between the mean values of loan sizes and within a given loan size limit at 95% confidence interval.

Analysis by loan period, purpose and size

The ACGS loan data consist of four levels of period (1981-1989, 1990-1999, 2000-2009 and 2010-2014), five levels of loan size (₦5,000 and below; ₦5,001-₦20,000; ₦20,001-₦50,000; ₦50,001-₦100,000; and Above ₦100,000) and seven levels of purpose of loan (Livestock, Fishery, Cash Crops, Food Grains, Root and Tubers, Mixed Farming and Other Enterprises). They were subjected to a two-way ANOVA with replications which produced three different ANOVA results. The first ANOVA result showed the effects of year group and loan purpose on ACGS loan data where loan size forms the basis of replication. The second ANOVA result showed the effects of loan size and loan purpose on ACGS loan data where year group forms the basis of replication. Lastly, the third ANOVA result showed the effects of year group and loan size on ACGS loan data where loan purpose forms the basis of replication.

The hypothesis for the two-way ANOVA used in this study goes thus:

Factor 'A' has '*r*' as the levels for Factor A and Factor 'B' has 's' as the levels for Factor B. Note that any of the three factors (loan size, year group and loan purpose) considered in this study could be paired together in coming up with the hypothesis for the two-way ANOVA. Putting the levels for factor 'A' as rows and the levels for factor 'B' as columns, the index '*i*' for the rows (i.e. factor 'A') and the index '*j*' for the columns (i.e. factor 'B'). Thus we use an '$r \times c$' table where the entries in the table were:

$\{x_{ij}: 1 \leq i \leq r, 1 \leq j \leq c\}$

The two-way ANOVA test for the differences in the mean values of loan across any of the two factors considered out of the three factors were tested by the joint hypothesis given below:

$H_0: \mu_1 = \mu_2 = ... = \mu_r$ and $H_0: \mu_1 = \mu_2 = ... = \mu_c$

(**Table A**)

α_i, and β_j are the main factor effects for A and B, respectively. $(\alpha\beta)_{ij}$ is the two-factor interaction effect for interaction AB.

Table 7 provides the ACGS loan data used in coming up with the three ANOVA results using two-way ANOVA. The three ANOVA results obtained in this study using the two-way ANOVA are presented in **Tables 8** to **10**.

Effects of year group and loan purpose on disbursement of ACGS loan

In can be deduced from **Table 8**, that year group revealed a $P_{value} = 0.002 < 0.05 = \alpha$ (or $F_{stat} = 5.161 > 2.6856 = F_{crit}$), therefore we reject the null hypothesis and conclude that at 95% confidence interval there is significant difference in the mean values of the loan disbursed between the year group. Likewise the results for purpose of loan revealed a $P_{value} = 0.016 < 0.05 = \alpha$ (or $F_{stat} = 2.733 > 2.1806 = F_{crit}$), which portends that we reject the null hypothesis and therefore conclude that at 95% confidence interval, there is a statistically significant differ-

Table A

Test Desired	Null Hypothesis Ho	Equivalent Ho
Effect of Factor A	$\mu_1 = \mu_2 = ...= \mu_r$	$\alpha_i = 0$ for all i
Effect of Factor B	$\mu_1 = \mu_2 = ...= \mu_c$	$\beta_j = 0$ for all j
Effect of Interaction A and B		$\alpha\beta_{ij} = 0$ for all ij

ence in mean values of loans across the purpose of loan disbursed. The results for the interactions between year group and purpose of loan revealed a $P_{value} = 0.591 > 0.05 = \alpha$ (or $F_{stat} = 0.890 < 1.6967 = F_{crit}$), which showed that these two factors did not interact with one another.

Effects of loan size and loan purpose on disbursement of ACGS loan

It can be deduced from **Table 9**, that loan size revealed a $P_{value} = 0.00002 < 0.05 = \alpha$ (or $F_{stat} = 7.624 > 2.4582 = F_{crit}$), therefore we reject the null hypothesis and conclude that at 95% confidence interval there is significant difference in the mean values of the loan disbursed between the loan size. Likewise the results for purpose of loan revealed a $P_{value} = 0.008 < 0.05 = \alpha$ (or $F_{stat} = 3.109 > 2.1861 = F_{crit}$), which portends that we reject the null hypothesis and therefore conclude that at 95% confidence interval, there is a statistically significant difference in mean values of loans across the purpose of loan disbursed. The results for the interactions between loan size and purpose of loan revealed a $P_{value} = 0.301 > 0.05 = \alpha$ (or $F_{stat} = 1.155 < 1.6215 = F_{crit}$), which showed that these two factors did not interact with one another.

Effects of year group and loan size on disbursement of ACGS loan

It can be deduced from **Table 10**, that year group revealed a $P_{value} = 0.0002 < 0.05 = \alpha$ (or $F_{stat} = 7.308 > 2.6802 = F_{crit}$), therefore we reject the null hypothesis and conclude that at 95% confidence interval there is significant difference in the mean values of the loan disbursed between the year group. Likewise the results for loan size revealed a $P_{value} = 0.000001 < 0.05 = \alpha$ (or F_{stat}

Table 7 ACGS loan data by year group, loan size and purpose (₦'000)

YEAR GROUP	LOAN SIZE	Livestock	Fishery	Cash Crops	Roots & Tubers	Food Grains	Mixed Farming	Other enterprises	Total
1981-1989	5,000 & Below	68,476.08	7,148.89	14,179.42	26,975.35	91,776.46	6,716.89	14,317.51	229,590.60
	5,001-20,000	14,965.53	1,562.40	3,098.93	5,895.49	20,057.86	1,467.98	3,129.11	50,177.30
	20,001-50,000	21,731.40	2,268.75	4,499.95	8,560.83	29,125.95	2,131.66	4,543.77	72,862.31
	50,001-100,000	6,164.11	643.53	1,276.41	2,428.28	8,261.58	604.64	1,288.84	20,667.39
	Above 100,000	64,958.28	6,781.63	13,450.99	25,589.55	87,061.65	6,371.83	13,581.98	217,795.91
	Total	176,295.40	18,405.20	36,505.70	69,449.50	236,283.50	17,293.00	36,861.21	591,093.51
1990-1999	5,000 & Below	44,241.69	8,590.30	22,864.57	76,698.69	325,453.28	1,192.81	25,443.44	504,484.78
	5,001-20,000	38,082.74	7,394.43	19,681.56	66,021.36	280,146.48	1,026.76	21,901.42	434,254.75
	20,001-50,000	14,088.32	2,735.50	7,280.99	24,423.93	103,637.36	379.84	8,102.21	160,648.15
	50,001-100,000	24,093.27	4,678.13	12,451.65	41,768.80	177,236.30	649.59	13,856.06	274,733.80
	Above 100,000	15,207.18	2,952.74	7,859.23	26,363.62	111,867.98	410.00	8,745.67	173,406.42
	Total	135,713.20	26,351.10	70,138.00	235,276.40	998,341.40	3,659.00	78,048.80	1,547,527.90
2000-2009	5,000 & Below	1,540.57	526.23	260.08	3,321.50	6,264.14	17.50	108.63	12,038.65
	5,001-20,000	200,127.19	68,359.53	33,786.10	431,477.77	813,740.67	2,273.35	14,111.53	1,563,876.14
	20,001-50,000	804,678.15	274,862.32	135,848.28	1,734,900.37	3,271,915.94	9,140.78	56,740.14	6,288,085.98
	50,001-100,000	976,948.41	333,706.48	164,931.48	2,106,318.10	3,972,387.04	11,097.69	68,887.40	7,634,276.60
	Above 100,000	2,860,474.53	977,082.18	482,914.25	6,167,233.85	11,631,025.62	32,493.69	201,700.16	22,352,924.28
	Total	4,843,768.85	1,654,536.74	817,740.19	10,443,251.59	19,695,333.41	55,023.01	341,547.86	37,851,201.65
2010-2014	5,000 & Below	5,048.65	1,225.30	674.83	7,838.10	8,730.12	1,947.43	1,126.96	26,591.39
	5,001-20,000	90,985.73	22,082.07	12,161.72	141,256.71	157,332.52	35,096.16	20,309.87	479,224.78
	20,001-50,000	553,510.67	134,336.02	73,985.72	859,333.62	957,130.63	213,507.09	123,554.86	2,915,358.61
	50,001-100,000	1,172,545.58	284,574.66	156,729.81	1,820,394.58	2,027,565.75	452,289.01	261,736.06	6,175,835.45
	Above 100,000	7,464,903.33	1,811,718.34	997,805.89	11,589,374.27	12,908,310.45	2,879,456.31	1,666,318.50	39,317,887.09
Total		9,286,993.96	2,253,936.39	1,241,357.97	14,418,197.28	16,059,069.47	3,582,296.00	2,073,046.25	48,914,897.32
Grand Total		14,442,771.41	3,953,229.43	2,165,741.88	25,166,174.77	36,989,027.78	3,658,271.01	2,529,504.12	88,904,720.38

= 9.492 > 2.4472 = F_{crit}), which portends that we reject the null hypothesis and therefore conclude that at 95% confidence interval, there is a statistically significant difference in mean values of loans across the purpose of loan disbursed. The results for the interactions between year group and loan size revealed a P_{value} = 0.00005 < 0.05 = α (or F_{stat} = 3.878 > 1.8337 = F_{crit}), which showed that there was interaction between year group and loan size. This is also showing that the disbursement of ACGS loan for the period covered were affected by the interaction between the effects of year group and loan size.

Means Comparison

The summary table of means differences obtained from New Duncan Multiple Range Test for the significant factors obtained in the study is presented in **Table 11**.

Means differences based on year group

The year group consist of four levels as shown in **Table 11**. It can be deduced from **Table 11** that means differences in the mean values of loans disbursed in years 1981 to 1989 and 1990 to 1999 are statistically the same. Likewise the means differences in the mean values of loans disbursed in years 2000 to 2009 and 2010 to 2014 are statistically the same. This means that the means differences in the mean values of loans disbursed in years 1981 to 1989 and 1990 to 1999 is statistically different from mean values of loans disbursed in years 2000 to 2009 and 2010 to 2014.

Means differences based on loan purpose

The purpose of loan consists of seven levels as shown in **Table 11**. It can be deduced from **Table 11** that means differences in the mean values of loans disbursed for the purpose of fishery, cash crop, mixed farming and other enterprises were statistically the same. Likewise the means differences in the mean values of loans disbursed for the purpose of livestock and root and tuber was statistically the same. More so, the means differences in the mean values of loans disbursed for the purpose of food grain was statistically different from other means values for which the loans were disbursed in the study. This means that loans disbursed within the period (1981-2014) investigated was highly used for food grains. Furthermore, results from **Table 11** showed that means differences in the mean values of loans disbursed for the purpose of fishery, cash crop, mixed farming and other enterprises are not the same with that of mean values of loans disturbed for the purpose of livestock and root and tuber.

Means Differences Based on Loan Size

Table 8 ANOVA table for effects of year group and loan purpose on ACGS loan data (₦'000)

SV	SS	df	MS	F	P_{value}	F_{crit}
Year Group	5.292E + 13	3	1.764E + 13	5.161	0.002	2.6856
Loan Purpose	5.605E + 13	6	9.342E + 12	2.733	0.016	2.1806
Interaction	5.475E + 13	18	3.042E + 12	0.890	0.591	1.6967
Error	3.828E + 14	112	3.418E + 12			
Total	5.465E + 14	139				

SV = Source of Variation, SS = Sum of Squares, df = Degree of Freedom, MS = Mean Squares

Table 9 ANOVA table for effects of loan siz|e and loan purpose on ACGS loan data (₦'000)

SV	SS	df	MS	F	P_{value}	F_{crit}
Loan Size	9.164E + 13	4	2.291E + 13	7.624	0.00002	2.4582
Loan Purpose	5.605E + 13	6	9.342E + 12	3.109	0.008	2.1861
Interaction	8.329E + 13	24	3.470E + 12	1.155	0.301	1.6215
Error	3.155E + 14	105	3.005E + 12			
Total	5.465E + 14	139				

SV = Source of Variation, SS = Sum of Squares, df = Degree of Freedom, MS = Mean Squares

Table 10 ANOVA table for effects of year group and loan siz|e on ACGS loan data (₦'000)

SV	SS	df	MS	F	P_{value}	F_{crit}
Year Group	5.292E+13	3	1.764E+13	7.308	0.0002	2.6802
Loan Size	9.164E+13	4	2.291E+13	9.492	0.000001	2.4472
Interaction	1.123E+14	12	9.360E+12	3.878	0.00005	1.8337
Error	2.896E+14	120	2.414E+12			
Total	5.465E+14	139				

SV = Source of Variation, SS = Sum of Squares, df = Degree of Freedom, MS = Mean Squares

The loan size consists of five levels as shown in **Table 11**. It can be deduced from **Table 11** that means differences in the mean values of loans disbursed for loan sizes of ₦5,000 and below, ₦5,001-₦20,000, ₦20,001-₦50,000 and ₦50,001 -₦100,000 were statistically the same. More so, the means differences in the mean values of loans disbursed for loan size of above ₦100,000 was statistically different from other loan sizes used in the study. This means that farmers are highly demanding for loan size of above ₦100,000.

Discussions and Findings

Access to Loans by Size

A total sum of ₦88.905 billion were accessed by 929,472 farmers as at December 2014, out of which the sum of ₦82.371 billion were accessed by 901,622 individual farmers; ₦1.901 billion by 11,274 informal groups; ₦3.082 billion by 14,518 Cooperatives; and ₦1.551 billion by 2,058 Limited Liability Companies. Hence, the average loan amount accessed by the various category of borrowers was ₦91,358.24, ₦168,624.25, ₦212,319.24 and ₦753,451.33 for individuals, informal groups, cooperatives and limited liability companies, respectively.

Similarly, ₦0.773 billion was granted to 225,414 farmers who had loan size of ₦5,000 and below; ₦2.528 billion by 150,709 farmers with loan size of between ₦5,001 and ₦20,000; ₦9.437 billion by 214,237 farmers with loan size of between ₦20,001 and ₦50,000 loan category. The sum of ₦14.106 billion was disbursed to 153,310 farmers whose loan size range between ₦50,001 to ₦100,000; and ₦62.062 billion disbursed to 185,802 farmers with loan size of above ₦100,000. Hence, the average loan for the loan category of ₦5,000 and below is ₦3,427.94; ₦16,770.95 was the average loan amount under the ₦5,001 to ₦20,000 category; ₦44,049.14 was the average loan amount for the ₦20,001 to ₦50,000 loan size; ₦92,006.48 was the average loan amount for the ₦50,001 to ₦100,000 category; and ₦334,022.31 was the average loan amount above ₦100,000.

Analysis of Variance

Table 11 Summary of means at various levels of year group, loan purpose and loan size for ACGS loan data (₦'000)

Factors	Levels	Definition of each level based on factor involvement	ACGS loan data (₦'000)
Year Group	1	1981–1989	1.69E + 4[a]
	2	1990–1999	4.42E + 4[a]
	3	2000–2009	1.08E + 6[b]
	4	2010–2014	1.04E + 6[b]
Loan Purpose	1	Livestock	7.22E + 5[ab]
	2	Fishery	1.98E + 5[a]
	3	Cash crop	1.08E + 5[a]
	4	Root & tuber	1.26E + 6[ab]
	5	Food grains	1.85E + 6[b]
	6	Mixed farming	1.83E + 5[a]
	7	Other enterprises	1.26E + 5[a]
Loan Size	1	₦5,000 & Below	2.76E + 4[a]
	2	₦5,001–₦20,000	9.03E + 4[a]
	3	₦20,001–₦50,000	3.37E + 5[a]
	4	₦50,001–₦100,000	5.04E + 5[a]
	5	Above ₦100,000	2.22E + 6[b]

Means with different letters within the same column are statistically different from each other at $p \leq 0.05$

Mean value of loans across category of borrowers

The comparison of the differences in mean value of loans across the various categories of borrowers was significant at 95% confidence interval and hence the null hypothesis was rejected. This confirmed the direction of available data presented in **Table 1** under the ACGS which showed that 92.65% (₦82.371 billion) of the total amount guaranteed under the ACGSF were disbursed to individual farmers.

Mean value of loans across loan limits

The study rejected the null hypothesis of 'no difference in the mean value of loans guaranteed across the various loans'. This implies the need for a review of the loan limits under the scheme as it seems that time has closed the gap along the loan limits. Available data as contained in **Table 4** showed that when the loan limits was ₦5,000 and below more farmers patronised the Scheme in its earlier years. With inflation and the element of time as a variable, beneficiaries now request for larger loan amounts of between ₦50,001 and ₦100,000 and also loans above ₦100,000. Of the total loans guaranteed to 225,414 borrowers in the loan limits of ₦5,000 and below category, 223,425 of the borrowers representing 99.12% that benefitted within this loan limit were prevalent in years 1981 to 2000. Conversely, 97.27 and 99.21% of beneficiaries who obtained loan size of ₦50,001-₦100,000 and above ₦100,000, respectively were guaranteed between 2001-2014.

Mean value of loans by purpose, period and loan size

In the analysis showing the purpose for which the loans were designated under the Scheme and the period covered as shown in **Table 7**, the result rejected the null hypothesis of 'no significant difference in both the mean value of loans disbursed by purpose, period (year group) and loan size. This was

contained in the ANOVA results presented in **Tables 8** to **10**. The ACGS data presented in **Table 7** also showed that 41.61% of the loans disbursed during the period covered (1981-2014) went to food grains, 28.31% of the total loans were disbursed to roots and tubers, and 16.25% of the loans were disbursed to livestock, while the remaining 13.83% went to fishery, cash crops, mixed farming and others.

Similarly, the result on the mean value of loans by period showed differences across periods. This is further buttressed by the data presented in **Table 7** which showed that 55.02% of total loans were disbursed between 2010 and 2014; while 42.58% was disbursed during 2000-2009; 1.74% was disbursed between 1990 and 1999. Only 0.66% was disbursed during 1981 to 1989. This result further strengthens the earlier submission under the mean number of loans across loan limits as the element of time seems to have skewed the performance of the Scheme in favour of more recent years.

This is in conformity with the fact that the disbursement were actually carried out across loan purposes over the years with no relationship between the purpose and size of loan. This is also contained in **Table 9** where both factors did not interact with one another.

The ACGS and agricultural productivity

The ACGS Fund is most likely to be the only functional agricultural finance scheme in Nigeria to date and sustainably encouraged the banking sector to lend to the agricultural sector directly from their balance sheet. Since its inception to December 2014, the Fund provided guarantees to more than ₦88.905 billion disbursed to mostly small holder farmers often considered as high risk clients. Despite this risk factor, disbursements under the Scheme continued at an annual incremental value of ₦323,044.00 from 1981 to 2014 (**Fig. 1**).

The ACGS fund targeted small holder farmers who constituted more than 75% of Nigeria's farming population. The Food and Agriculture Organization (FAO, 1989) categorized farmers into three different groups based on the concept of "marketable surplus" as a percentage of total production. In Nigeria, small holder farmers fall under the subsistence group and have a marketable surplus of under 25% of their total production. The ACGS Fund has sustained its effort at targeting this group of farmers with the aim of increasing their productivity to attain a marketable surplus of above 50% of production. The results of the descriptive analysis corroborated this assertion by showing that 92.65% of the loans disbursed were to individual farmers. Further analysis of loan sizes using one-way ANOVA (F05, (4,165) = 2.4264, P_{value} = 0.00000003, F_{stat} = 9.3659) revealed that over the 34 years of the existence the mean values of ACGS loan within a given loan size continue to increase, reasons which could be attributed to increased loan demand (which has effect on farmer productivity) as a result of the need for more loans by farmers to either vertically expand (through use of improve seed varieties and farm inputs) or horizontally expand (through land and scale expansion) farm operations.

The ACGS has acted as an effective collateral substitute for farmers who lack the capacity to meet the collateral requirements of borrowing from financial institutions. As stipulated in the ACGS guidelines, only loans below ₦20,000.00 were to be granted to farmers without tangible security. The results and findings of the descriptive analysis showed 376,120 out of the 929,472 farmers which represents 40.47% accessed ACGS loans with sizes below or equal to ₦20,000.00. This farmer's group when rated by the size of their loans showed that they belong to the very small holder farmers. It could therefore be deduced that without the ACGSF, this farmer's group would not have been able to access the loans from commercial banks. Their ability to access the loans has no doubt improved their farming operations and increased their farm productivity and socio-economic status.

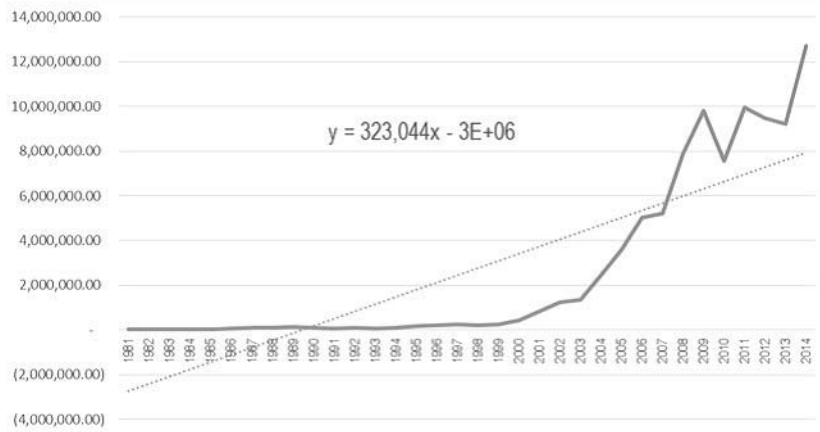

Fig. 1 Trend in Loans Guaranteed from 1981 to 2014 (₦'000)

Conclusion

The Nigerian agriculture landscape is dominated by small holder farmers sparsely located across the Country. Hence there is a huge potential to be tapped if the productive capacities of these farmers are improved. The ACGS Fund as one of the oldest and active government

interventions in the agricultural sector has been strategic in providing the needed assistance to increase the productive capacities of these farmers. This paper has been able to establish that ACGS Fund assisted small holder farmers in accessing small loans for their farm business by providing 75% guarantee to banks in case of default. The sum of ₦88.905 billion had been disbursed from their balance sheet to the risky segment of the agricultural credit market. However, it is required that the operations of the Scheme need to be overhauled in line with current realities. Generally, the ACGS has improved the productivity of farmers in Nigeria over the years.

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Farm Mechanization Strategy for Promotion of Improved Equipment Under Animal Based Farming in Nagaland-India

by
R. K. Tiwari
Research Engineer
SK Chauhan, Assistant Agril. Engineer
AICRP on UAE, CAEPHT, Ranipool-Sikkim
INDIA
rk96tiwari@gmail.com

Abstract

Agriculture is the most important economic activity in Nagaland. Principal crops include rice, corn, millets, pulses, tobacco, oilseeds and sugarcane. It provides livelihood to around 70% population. The total cultivated area of state includes 70% hill and 30% plain region. It has total cultivable are of 721,924 hectares of which 70% is in the hilly region up to 2,500 meters and the rest 30% in the foot hills symbolizing as the rice bowl of the state. Rice is the staple food for most of the people and occupies about 70% of the total cultivated area contributing to about 75% of total food grain output in the state. About 90% land belongs to individuals and the land is divided into small sizes and scattered in different locations. The total livestock were 1.41 million in the Nagaland state of country. The package of improved equipment can reduce the human drudgery and there will be savings of input under animal based farming system both under terrace farming and jhum cultivation. The cost of package for jhum cultivation was worked out as $291.059. Under terrace farming without rice equipment the package cost was worked out as $783.689 under animal based farming in hills in Nagaland. The equipment package for rainfed rice cultivation in hills was estimated as $1,165.227. The requirement of total packages (14,256 no.) will cost $9.99 million for mechanizing 5% cultivated area in the hill state under animal based farming system through selective mechanization. The total benefits from improved equipment package in mechanizing 5% of cultivated area were estimated as $6.763 million.

Keywords: Cultivable, Jhum, package, human drudgery, terrace farming, selective mechanization.

Introduction

Livestock sector contributed 4.8-6.6% of the total gross domestic product during last decade in the country. The total livestock in north eastern region were 25.138 million. In north eastern region of country there is tremendous scope of organic farming due to availability of 7.33 million tones of dung annually from 3 million cattle, 0.16 million

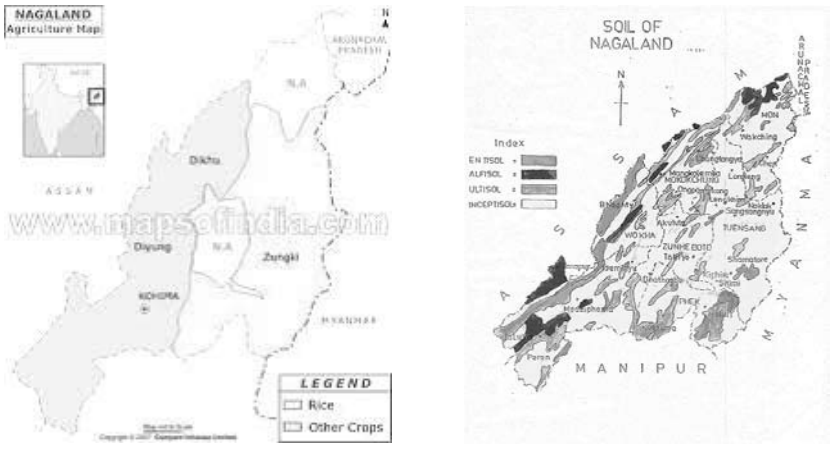

Fig. 1 Agriculture and soil map of Nagaland
(Source : Deptt. of Agriculture, Got of Nagaland-India)

buffaloes and 16,000 horses, ponies and yaks (Census, 2011).

Nagaland of eleven districts lies between 93020 to 95015 E longitude and 25060 to 26040 N latitude in the extreme North Eastern end of India and its topography is mostly mountainous. Nagaland encompassed a total area of 16,579.0 sq km comprising 6.32% of North East and 0.5% of the total land area of the country. The altitude varies for 25 (Dimapur) to 3,840 MSL (Saramati peak, Twensang district). The average height of the hilly terrains is 900-1,200 m MSL. The slopes level of the hilly terrain varies from 40-60%. The annual average rainfall of the state is 200-300 cm with the highest during June to mid October and the relative humidity from 65-90 percent. The economy of the state is predominantly agriculture-based; 68% population engaged in agriculture and allied activities. The total population of the state is 1,980,602 comprising of 1,025,707 males and 954,895 females with sex ratio 909 and population density 120 per sq km. The rural population numbering 1,406,861 comprises of 724,595 males and 682,266 females. The agriculture and soil map of Nagaland are represented in **Fig. 1** which indicate coverage of rice and other crops and four types of soils (Anonymos, 2013).

Table 1 Area, Production & Yield of Cereals, Pulses, Oil seeds & Commercial crops (Area in '000 hectares, Production in '000 metric tons and Yield in Kg/ha)

Crop		2010-11
Cereal	Area	264.40
	Production	531.86
	Yield	2,011
Pulses	Area	34.43
	Production	36.46
	Yield	1,058
Sub-total, Foodgrains	Area	298.83
	Production	568.32
	Yield	1,901
Oilseeds	Area	65.84
	Production	67.53
	Yield	1025
Commercial crops	Area	29.40
	Production	392.17
	Yield	13,339
Total	Area	394.07
	Production	1,028.02
	Yield	2,608

Department of Agriculture, Government of Nagaland

Farmers practice four diversified forms of traditional agriculture, viz. i. the Jhum (Shifting Cultivation) System ii. Terrace Rice Cultivation (TRC).The jhum cultivation is a traditional method of cultivation pursued by farmers. The jhum cycle normally ranges between six and ten years depending upon the area held by farmers. Area under jhum cultivation was 90,940 hectares as compared with 83,330 hectares under TRC in 2009. There are four distinct agro climatic zones, viz. a. High hills b. Low hills c. Foot hills and d. Plain areas, each having specific cropping patterns. By and large rice, is the principal crop grown in all zones, mostly as single crop and sometimes with other crops viz. maize, millets and vegetables. Farmers raise a number of crops, viz. i. Cereals (rice, maize, sorghum, millets, wheat, barley and oat), ii. Pulses (arhar, urad, cowpea, beans, rajmah, horse gram, pea and lentil), iii. Oil seeds (groundnut, soybean,

Table 2 Animal based farming system package of improved equipment for terrace cultivation Nagaland

Improved equipment	Unit price, $	Effective field capacity, ha/h	Cost of of operation, $/ha	Command area, ha/season
Animal drawn wing plough (size: 200 mm)	15.384	0.020	28.923	1.5
Animal drawn improved clod crusher-leveler-planker-puddler (size: 700 mm)	76.923	0.060	27.692	1.5
Animal drawn improved wedge plough (size: 230 mm)	15.384	0.025	24.615	1.5
Animal drawn two row improved seed drill (size: 700 × 950 × 740 mm)	38.461	0.600	8.07	1.5
Animal drawn improved potato digger (Size:600 mm)	40.769	0.065	18.923	1.5
Manual wheel hand hoe (Size:210 mm)	15.384	0.01	39.23	1
Manual knapsack sprayer	5.384	0.05	23.076	1
Manual cono weeder (Size: 210 mm)	27.692	0.01	30.769	1
Improved sickle	0.923	0.005	73.846	1
Tubular maize sheller	0.923	20 kg/h	19.692	1
Animal drawn multi-crop planter	100	0.07	11.538	1
Motorized wire-loop thresher	153.846	150 kg/h	21.538	1.5
Manual 4 row rice transplanter	100	0.020	20.769	1
Manual 4 row paddy drum seeder	100	0.030	14.615	1
Multi-crop plot thresher (Single phase electric motor, 1 hp)	538.461	125 kg/h	9.230	1.5
Manual double screen cleaner (size 900 × 600 × 140 mm)	38.461	150 kg/h	7.692	1
Grubber weeder with handle (size: 1750 × 240 × 1060 mm)	5.384	0.005	73.846	1
Naveen dibbler (size: 280 × 260 × 1060 mm)	10	0.028	12.307	1
Total	1,165.23			

castor, sesamum, sunflower, rapeseed and mustard), and iv. Commercial crops (sugarcane, cotton, jute, mesta, potato, tea, tapioca, colocossia) during the Kharif and Rabi season. While 90% of cereals and commercial crops are raised during the Kharif season about 55% of pulses and oilseed crops are raised during the Rabi season. The productivity of crops (**Table 1**) grown in Kharif is higher than that in Rabi (Yojana, 2012).

Materials and Methods

The total farm power available in the state is 0.336 kW/ha against required power 1.5 kW/ha. Most of the agriculture operations are performed by using animate power sources. The stationary farm power sources; irrigation pump and electric motor are commonly used in irrigated area and use of mechanical mobile farm power sources is negligible. The availability of human power is 53.1%., animal power 45.9% and mechanical power is 1.0%. Since most of the farm operations in Nagaland are done using animal power hence, there is great scope of selective mechanizing in the tribal belt where small hand tools are being used resulting in human drudgery (Singh et al., 1996).

The selective mechanization for potential crops based on animate power sources has scope for introducing suitable small, light weight, higher work rate and low cost equipment. Considering farm mechanization initially for 5% of the cultivated area using proven designs available, for potential crops would be enough through development of skill for adoption of improved equipment. Considering 1.5 ha command area using animal drawn improved equipment and 1 ha command area for manually operated improved equipment, the benefits to be accrued on the basis of savings in labour, time, cost of operations, inputs savings and reduction in human drudgery were worked out for different agricultural operations in the eight districts of Nagaland which can increase yield from 7 to 10% (Pandey et. al, 2006). Since women in rural region of state constitutes 48.49% so women friendly improved small hand operated and light weight animal drawn equipment can also be effective to mechanize different agricultural operations. The seedbed preparation operations require common equipment for ploughing, puddling, leveling, ridge making etc for all crops sown in the hills under terrace cultivation. The package of animal based farming for terrace conditions consists of animal drawn improved equipment and few manually operated equipment for interculture, harvesting and maize shelling operations. Similarly for jhum cultivation, light weight, simple, low cost improved equipment have been incorporated which can be operated by tribals and especially women operators for reducing human drudgery. The package for jhum may be made available individually but package for animal based farming will need skill development of users for their use in terrace condition. Animal based farming system package of improved equipment consisted of 18 equipment of proven designs suitable for terrace cultivation in Na-

Table 3 Package of improved equipment for jhum cultivation selective mechanization

Name of the equipment	Unit price ($)	Effective field capacity, ha/h	Cost of operation, $/ha	Command area, ha/season
Hand ridger (size: 1690 × 240 × 900 mm)	350	0.033	1,550	1
Naveen dibbler (size: 280 × 260 × 1060 mm)	650	0.028	1,850	1
Grubber weeder (size: 1750 × 240 × 160 mm)	650	0.005	4,500	1
Improved sickle	60	0.005	4,000	1
Tubular maize sheller	60	20 kg/h	900	1
Pedal operated paddy drum thresher	2,500	70 kg/h	750	1.5
Manual wheel hoe	350	0.01	2,550	1
Manual cono weeder	1,800	0.008	2,000	
Animal drawn improved wedge plough	1,000	0.025	1,600	1.5
Manual paddy drum seeder (2 row)	2,500	0.02	1,250	1

Table 4 Total package requirement for selective mechanization in Nagaland

Crop	Area, ha	Area to be mechanized through animal based farming system equipment, (5%), ha	Number of packages of improved equipment	Cost of package in $ million,
Paddy				
Jhum system	90,940	4,547	4,547	1.323
Terrace system	83,330	4,166.5	2,778	3.237
Maize	6,6420	3,321	2,214	1.735
Pulses	3,4430	1,721.5	1,148	0.899
Oilseeds	6,5840	3,392	2,262	1.772
Commercial crops	2,9400	1,470	1,307	1.024
Total	370,360	18,618	14,256	9.99

galand as mentioned in **Table 2**. The number of equipment package for rainfed rice cultivation in hills was estimated 2,778 no. costing $3.237 million needed for animal based farming system if mechanized in 5% of rice cultivated area. Package of improved equipment for jhum cultivation selective mechanization will require $1.323 million for introducing package which has combination of manually and animal drawn equipment for the potential crops as listed in **Table 3**. The requirement of total packages (14,256 no.) will cost $9.99 million for mechanizing 5% cultivated area in the hill state through selective mechanization as indicated in **Table 4**.

The college of Agricultural Engineering and Post Harvest Technology (CEAPHT-CAU) Centre of All India Co-ordinated Research Project on Increased Utilization of Animal Energy with Enhanced and System Efficiency (ACIRP on UAE) organized Awareness Day Programme jointly on efficient management of draught and pack animals (Mithuns and Ponies) at Porba village in KVK Phek district of Nagaland under National Research Centre on Mithun at Jharnapani on January 24, 2014. The programme was attended by 35 farmers having mithuns at Porba village.

The Krishi Vigyan Kendra, village Porba, district Phek briefed about the mithuns status at KVK farm (57 mithuns) and in Porba village (150 mithuns) and their present uses by farmers for meat and milking purposes. She stated the price of mithuns varying from Rs. 50, 000 to 80,000 for adult mithuns (4-5 years age).

AICRP on UAE Centre, Ranipool -Sikkim explained the benefits of improved equipment suitable for domesticated mithuns and urged to take the advantage of small hand tools and light weight improved equipment due to their higher output capacity and cost effectiveness for different unit operations in regional agriculture. The demonstration trials for efficient use of domesticated mithuns (average weight:400 kg, age:5 years) using improved yoke and single animal adjustable collar harness were conducted for ploughing operations NRC on mithuns, Jharnapani, Nagaland. The demonstrations of adjustable collar harness suitable for domesticated single mithun and improved yoke for paired domesticated mithuns were shown in **Fig. 2** and **Fig. 3** respectively.

The test trials for efficient use of domesticated mithuns (average weight: 400 kg, age:5 years) using improved yoke and single animal adjustable collar harness were conducted for ploughing operations at research farm of NRC on mithuns, Jharnapani, Nagaland (**Fig. 4**). The body weights of adult domesticated mithuns used for ploughing were

Table 5 Estimated benefits of package of improved equipment for mechanizing 5% of the cultivated area

Improved equipment	Annual benefits per unit, $	Benefit of unit/ha, $	Value 5% of the cultivated area	Total benefit considering 5% of cultivated area, $ million
Animal drawn wing plough (size: 200 mm)	34.61	23.076	18,518	0.427
Animal drawn improved clod crusher-leveler-planker-puddler (size: 700 mm)	46.153	30.769	18,518	0.569
Animal drawn improved wedge plough (size: 230 mm)	29.538	19.692	18,518	0.364
Animal drawn two row improved seed drill (size: 700 × 950 × 740 mm)	10.769	10.769	13,971	0.15
Animal drawn improved potato digger (size:600 mm)	38.076	25.384	1,470	0.037
Manual wheel hand hoe (size:210 mm)	53.076	53.076	13,971	0.741
Manual knapsack sprayer	30.769	30.769	18,518	0.569
Manual cono weeder (size: 210 mm)	33.846	33.846	8,713.50	0.294
Improved sickle	15.384	15.384	18,518	0.284
Tubular maize sheller	17.23	17.23	3,321	0.057
Animal drawn multi-crop planter	38.461	19.23	9,804.50	0.188
Motorized wire-loop thresher	64.615	43.076	8,713.50	0.375
Manual 4 row rice transplanter	38.461	38.461	8713.5	0.335
Manual 4 row paddy drum seeder	53.846	53.846	8,713.50	0.469
Multi-crop plot thresher (Single phase electric motor, 1 hp)	27.692	18.461	5,042.50	0.093
Manual double screen cleaner (size 900 × 600 × 140 mm)	30.769	30.769	18,518	0.569
Grubber weeder with handle (size: 1750 × 240 × 1060 mm)	27.692	27.692	9,804.50	0.271
Naveen dibbler (size: 280 × 260 × 1060 mm)	12.307	12.307	8,334.50	0.102
Hand ridger	55.384	18.461	9,804.50	0.181
Pedal operated wire loop thresher	123.076	74.461	8,713.50	0.648
Total	781.754		596.759	6.763

Awareness day for mithuns application in modern agriculture and On-farm trials of domesticated mithuns

408 kg and 466 kg. The girth and overall length of mithuns used in test trial varied 2.05-2.06 m and 1.37-1.44 m respectively. The test trial using single mithun (Weight : 466 Kg, age: 5 years) resulted in increase of pulse rate/ min (30.23%), respiration rate/min (54.83%) and body temperature (3.20%) during test trials of 30 minutes. The average values of speed of mithun and draft were 2.39 km/h and 26 kg respectively at 80 mm depth of ploughing. The work rate was 0.04 ha/h.

For double mithuns (**Fig. 5**), the average speed of operation and depth of ploughing values were 2.98 km/h and 100 mm respectively. The effective field capacity and field efficiency were 0.036 ha/h and 75% respectively. The cost of operation for ploughing operation varied Rs 1,360-1,400/ha which saved 65% in cost of operation as compared to traditional ploughing practice.

Conclusions

Fig. 2 Adjustable collar harness for single mithun

- The requirement of packages of improved equipment can bring down the stress and livelihood can be boost up in agriculturally backward state which need immediate of mechanization in different agricultural operations for potential crops under animal based farming system.
- The cost of package for jhum cultivation was worked out as $291.059.
- Under terrace farming without rice equipment the package cost was worked out as $783.689 under animal based farming in hills in Nagaland.
- The cost of each package of equipment for rainfed rice cultivation in hills was estimated as $1,165.227.
- The requirement of total packages (14,256) will cost $9.99 million for mechanizing 5% cultivated area in the hill state under animal based farming system through selective mechanization.
- The total annual benefits from each package were estimated as $781.754 and benefits from single package will be $596.759/ha.
- For mechanizing 5% cultivated area in Nagaland-India the estimated investment on package of improved equipment would be $6.763 million.

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Fig. 3 Improved Yoke for use on pair of mithuns

Fig. 4 Single mithun application for ploughing

Fig. 5 Tillage operation using double

Performance Evaluation of Self-Propelled Groundnut Combine

by
T. Senthilkumar
Senior Scientist
Central Institute of Agril. Engineering, Bhopal
INDIA
thasekumar@gmail.com

D. Manohar Jesudas
Professor

D. Asokan
Professor and Head

Dept. of Farm Machinery, Tamil Nadu Agricultural University, Coimbatore
INDIA

Abstract

Groundnut is conventionally harvested either by manual pulling if the soil moisture is adequate or hoeing with hand hoe followed by manual pulling. In some places, the field is ploughed with a mould board or country plough to uproot the plants. In both methods, much of the human energy is exerted, involving drudgery and fatigue. Even groundnut harvester and thresher have become popular among the farming community during the last few years, collection and transportation of harvested groundnut plants are becoming labour intensive. This situation necessitates the introduction of groundnut combine. With this objective, a Chinese made self-propelled combine for groundnut suitable for harvesting and threshing green pods was procured and evaluated at Tamil Nadu Agricultural University and at farmer's fields in Tamil Nadu. It was observed that the average threshing efficiency was around 80.0% and the average damage to the pods was 16.10%. Modifications were done to the threshing drum and two designs of stripping drum were tested for their performance. It was observed that, stripping drum with rubber vane resulted in 94.2% threshing efficiency and 1.6% pod damages.

Introduction

India is the second largest producer of groundnut after China. Groundnut is the major oilseed in India in terms of production. On an average it accounts for 31.81% of the oilseeds. The annual production of seed and oil are 5.8 and 1.5 million tonnes, respectively. About 80% of the total groundnut produced in India undergoes processing so that it can be utilized as oil and cake. Around 75% of the crop is produced in kharif season (June-September) and remaining 25 percent in rabi season (November-March). Gujarat was the largest producer of groundnut contributing 38.14% of the total production and followed by Tamil Nadu (15.46%), Andhra Pradesh (12.25%), Rajasthan (11.55%) and Karnataka (7.44%) during 2011-12.

At present, groundnut occupies an area of 5.31 m ha in India with a production of 6.93 mt. About 91% of total groundnut area and production are confined to the states of Gujarat, Tamil Nadu, Andhra Pradesh, Karnataka, Maharashtra and Rajasthan. In Tamil Nadu, groundnut is cultivated in an area of 0.45 m ha with a production of 1.07 mt of pods. The average pod yield was 2,382 kg ha^{-1} during 2011-12. Out of the total area grown under groundnut, the irrigated rabi groundnut occupied about 37.8% during 2011-12.

Groundnut is conventionally harvested either by manual pulling if the soil moisture is adequate or hoeing with hand hoe and followed by manual pulling. In some places, the field is ploughed with a mould board or country plough to uproot the plants. In both the methods, much of the human energy is exerted, involving drudgery and fatigue. The moisture content of the soil influences the ease of harvesting in groundnut.

Yang-ren (1983) developed a small self propelled one way operation groundnut combine at Taiwan. The combine was driven by 15 hp diesel engine. An automatic hydraulic system was used to grasp the stem. In order to grip the stems out of the field, a special form of chain bar or embanking ditching belt was developed. A string type of pod stripping mechanism was attached to the combine for stripping.

Thangavelu and Swaminathan (1986) studied the performance of seven types of stripping mechanism, namely plain beater, star type, delta type, eye type, nail type and screw type for groundnut. The study revealed as that the rotor speed varied from 2.83 to 4.65 ms^{-1}, output and damage percentage were calculated at different levels of moisture content of the crop ranging from 15 to 40%. The study established that the screw type mechanism was the best.

Yang *et al*. (2009) designed and

conducted comparative test of soil removing device of peanut combine harvester. Soil removing device directly affected the performance of the follow up peanut stripping devices. Three soil removing devices were designed for the digging and pulling in peanut combine harvester viz., forward removing soil device by swaying up and down, reverse removing soil device by swaying up and down and transverse removing soil device by swaying in landscape orientation. It was observed that forward removing soil device by swaying up and down was optimal soil removing device according to the soil removal rate.

Zhichao *et al*. (2010) conducted an experiment on half feed peanut combine harvester to study stalk clamping height, clapping frequency and amplitude of clod removing unit, rotate speed of peanut picking roller, clamping chain speed, moisture content of soil and time of harvest. It was concluded that soil moisture from 8% to 15% was suitable for peanut harvesting in sandy loamy soil. Dropped peanut loss during clod removing increased gradually with the delay of harvest time. The dropped peanut loss rate was more than 2% when the snap force of peanut root was less than 5 N. The optimum stalk clamping height ranged from 150 to 200 mm, keeping total loss rate and clod content less than 6% and 4%, respectively. Lower frequency and smaller amplitude of clod clapping operation contributed to smaller dropped peanut loss rate, but higher clod content, higher frequency and larger amplitude contributed to lower clod content and higher dropped peanut loss rate. The peanut loss of peanut picking operation was kept at lower level with higher picking roller speed and lower clamping chain speed. In this experiment, loss rate of peanut picking was 2.79% at 390 rpm of picking roller speed and 0.5 m/s of clamping chain.

Even groundnut harvester and thresher have become popular among the farming community in India during the last few years, collection and transportation of harvested groundnut plants are becoming labour intensive. This situation necessitates the introduction of combine for groundnut. With this objective, a Chinese made self-propelled combine suitable for harvesting and threshing green pods of groundnut was procured and evaluated at Tamil Nadu Agricultural University and farmer's fields in Tamil Nadu.

Materials and Methods

For this study, a commercially available groundnut combine from China was purchased and evaluated in Tamil Nadu field condition (**Fig. 1**). The cropping system followed in China for this combine harvester was raised bed farming system and was shown in **Fig. 2**.

Functional Components of the Groundnut Combine

The self propelled groundnut combine harvester consists of following components:

Prime mover (or) engine

A 17.6 kW single cylinder water cooled engine is the prime mover. It consists of clutch, braking system, steering system and power transmission gear box. The steering is by hydraulic cylinder fitted to the rear wheels of the groundnut combine.

Power transmission system

The power was taken directly from the engine to all the functional components through clutch. Power for the gathering assembly was taken from the "V" belt. The power was transmitted to the chain conveying system by "V" belt. The power to the stripping system, cleaning system and pod conveying system was transmitted by using chain and sprocket arrangement.

Digging assembly

The digging assembly consists of two flat blades of 230 × 100 × 6 mm in size and an adjustable shank of 30 mm diameter mild steel rod. Provision is available to adjust the depth of operation of digging blade by adjusting the shank length.

Gathering system

The gathering system consisted of two vertical conveyors with gathering units. The width of the vertical conveyor is 80 mm. The length of each gathering unit is 140 mm. Each gathering unit is fixed at a spacing of 160 mm from each other. The gathering unit is attached with the chain drive. The two vertical gathering assemblies are spaced at a distance of 470 mm. This gathering assembly is used to collect and guide the groundnut crop to the conveying system.

Chain conveying system

The chain conveying system is used to pick up the crop, convey

Fig. 1 Commercially available groundnut combine

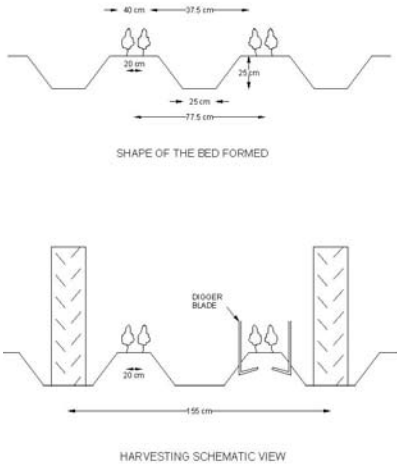


Fig. 2 Raised bed system required for harvesting by groundnut combine

Fig. 3 Groundnut crop stand in raised bed system

Fig. 4 Operational view of groundnut combine

the crop to the stripping system and discharge the stripped vines. This system consists of two endless chains which are connected to the transmission system through "V" belt. The conveying chain is fixed on the 60 × 32 mm base section of size 3760 × 310 × 160 mm.

Stripping system

The stripping system consisted of two counter rotating stripping drums of size 560 × 60 mm. On the periphery of the drum, four blades were fitted. The stripping drums were fitted below the chain conveying system, in such a way that the root position of the groundnut crop would come into contact with the revolving blades for stripping. The stripping baffles were used to strip the pods by impact force.

Cleaning system

The cleaning system consisted of a blower and a oscillating sieve. The blower was fitted at the bottom most portion of combine harvester. This was used to winnow the light foreign material from the pods. The oscillating sieve was fitted directly below the stripping system. This was used to collect the pods, to separate the clean pod and to convey the clean pods to augur conveyor system.

Pod collecting system

The pod collecting system consisted of screw conveyor, bucket elevator and collection chamber. The screw auger was fitted at the tail end of the combine harvester, nearer to the oscillating sieve. The screw augur discharged into a collection chamber from where the bucket elevator system lifted the pods. The bucket elevator system was used to lift the groundnut pods to the collecting chamber. The collecting chamber was provided with the pod collection bag holder.

Evaluation of Self Propelled Groundnut Combine

The groundnut combine was evaluated in the laboratory and field conditions for its performance. Field layout with raised bed system and crop stand is shown in **Fig. 3**. The soil and crop characteristics recorded during the testing of the groundnut combine are detailed below.

Soil parameters

The soil parameters; type of soil and moisture content of the test field were measured.

Crop parameters

The crop parameters that influence mechanical harvesting of groundnut crop were identified as plant population, root length, pod depth, crop height, pods per plant and crop moisture.

Evaluation Parameters

The self-propelled combine harvester was evaluated for harvesting groundnut crop cultivated on raised bed (**Fig. 4**). The harvesting efficiency, stripping efficiency, cleaning efficiency and percentage broken pods were measured during the evaluation of groundnut combine. The stripping drum speed directly influenced the stripping efficiency. To optimize the stripping drum speed, three levels of speed. viz., 200, 300 and 400 rpm were selected for the study.

Results and Discussions

For evaluating the self propelled groundnut combine, crop was cultivated on raised bed system. Sowing was done by using the tractor operated raised bed former cum seed drill specially developed to suit the operation of the combine harvester.

The crop stand and the other crop parameters were measured. The details of crop parameter measured are given in **Table 1**.

Trials were conducted at TNAU, Coimbatore and at Farmers field near Kinathukadavu. The results of the field observations are given in

Table 1 Crop parameters

Crop parameters	Value	Value
Variety	CO 3	TMV 7
Row spacing, mm	200 × 100 (paired row in raised bed)	200 × 100 (paired row in raised bed)
Plant population, No./ m^2	28 (conventional system – 36)	28 (conventional system – 36)
Pod depth, mm	0 to 80	0 to 65
Average crop height, mm	310	240
Moisture content of crop, %	64	68

Table 2.

From the results it was observed that, the average digging efficiency of the combine was 98% for both varieties. The average picking and conveying efficiency of conveying system was recorded as 93.5 and 92.5% for variety CO 3 and TMV 7, respectively. The total threshing losses were recorded as 20.07 and 19.75% with the average threshing efficiency of 79.90 and 80.25% for varieties CO 3 and TMV 7, respectively. The average broken pod percentage and broken kernel percentage were recorded as 18.0 and 0.73%, respectively for variety CO3 and 14.12 and 0.55% for variety TMV 7. The average field capacity of the combine was recorded as 0.12 ha/h with the average stripping capacity of 942 and 837 kg/h for varieties CO 3 and TMV 7, respectively. The average fuel consumption of the combine was recorded as 2.44 L/h.

The field trials with the combined harvester indicated that there were two major problems in the functioning of the combine. They are low stripping efficiency and damage to the pods. This is due to the plant morphology and the beater arrangement. The beater for stripping the pods is conical in shape to ensure that the pods hanging below the conveyor at different levels are stripped when they come in contact with conical stripping drum at different points as they travel along the conveyor. The crop varieties in Tamil Nadu are bunch or semi spreading type. The pods are closely clustered around the base of the plant and most of the pods are within 0-80 mm of root spread. This combine harvester is made in China and is suitable for operating in crop that are tall and pods set at the end of long roots. The high level of unthreshed pods was due to the gap between the bottom of conveyor and vanes of the stripping drum. Hence, it was decided to modify the stripping drum by

a. Increasing the number of beater vanes and reducing the peripheral speed to decrease the damage to the pods
b. Provide four vanes with rubber flaps so that higher speed of rotation is possible without causing damage to the pods.

The stripping drums were fitted with four vanes and rubber flap of 10 mm thickness and 70 mm radial height were fitted to the four vanes. The modified stripping drum with rubber flap is shown in **Fig. 5**.

The performance of the stripper drum with the rubber flap was evaluated at three levels of drum speed of 200, 300 and 400 rpm and results are given in **Table 3**.

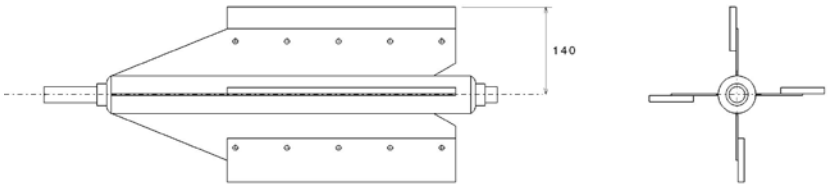
From the **Table 3**, it was observed that the stripping efficiency of 94.2% and pod damage of 1.6% could be obtained with the modified drum at drum speed of 300 rpm.

Conclusions

A Chinese made self-propelled groundnut combine suitable for harvesting and threshing green pods was procured. The combine harvester was evaluated under field

Table 2 Field performance of self propelled groundnut combine harvester

Particulars	Average values	Average values
Area covered, ha	1.55	0.82
Crop variety	CO 3	TMV 7
Height of the crop, cm	31	24
Vine pod ratio	2.6:1	3.3:1
Speed of operation, km/h	2.0	2.0
Moisture content of soil,% (wb)	15.75	17.5
Digging efficiency, %	98	98
Picking and conveying efficiency, %	93.5	92.5
Threshing losses total, %	20.07	19.75
Threshing efficiency, %	79.9	80.25
Sieve over flow, %	0	0
Broken pod, %	18.00	14.12
Broken kernels, %	0.73	0.55
Output capacity, kg/h	942	837
Field capacity, ha/h	0.12	0.12
Cost of operation, Rs/ha	2,583	2,373.5
Man power requirement, man days/ha	4	4
Fuel consumption, L/h	2.43	2.45



Side view Front view

Fig. 5 Modified drum fitted with rubber flap

Table 3 Results of laboratory test with rubber flap drums

Drum speed, rpm	Stripping efficiency, %	Pod damage, %	Unthreshed pod, %
200	85.3	5.25	14.7
300	94.2	1.6	5.8
400	87.8	8.16	12.2

conditions and the average threshing efficiency of around 80.0% and the average damage to the pods of 16.10% were observed. The average field capacity of the combine was 0.12 ha/h with the average stripping capacity of 942 and 837 kg/h for varieties CO 3 and TMV 7 respectively.

Modifications were done to the threshing drum and two designs of stripping drum were tested for their performance. It was observed that stripping drum with rubber vane resulted in 94.2% threshing efficiency and 1.6% pod damages.

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Prototype: A Ridge Profile Mechanical Power Weeder

by
D. S. Thorat
Scientist
Central Institute of Agricultural Engineering, Bhopal-462 038
INDIA
deepakthorat.iari@gmail.com

P. K. Sahoo
Principal Scientist
Division of Agricultural Engineering, Indian Agricultural Research Institute, New Delhi-110012
INDIA

Dipankar De
Principal Scientist
Division of Agricultural Engineering, Indian Agricultural Research Institute, New Delhi-110012
INDIA

Mir Asif Iquebal
Scientist
Indian Agricultural Statistical Research Institute, New Delhi-110012
INDIA

Abstract

Weeding is one of most important operation in crop cultivation. Although, there are several methods are available of mechanical weeding, but weeding operation poses a special problem in ridge planted crop. Therefore, to address this problem a ridge profile power weeder was developed with 2.20 kW petrol-start kerosene-run engine and evaluated for its performance in terms of weeding efficiency, plant damage percentage and field capacity. Weeder comprised of main frame, handle, cutting blades, rotor shaft, belt and pulley, engine and ground wheel. Experiments were conducted at three different levels of each parameter viz, soil moisture content (15.26 ±0.96, 12.42 ±0.52 and 9.44 ±0.68%), blade types (L-type, C-type and Flat-type) and gang speed (160, 180 and 200 rpm). Results revealed that, C-type blades were most suitable at gang speed of 200 rpm and 15.26 ±0.96% (d.b) soil moisture content with average weeding efficiency, plant damage, actual field capacity of 83.93%, 1.77%, and 0.066 ha h^{-1}, respectively. The total estimated cost of machine was Rs. 27,600 ($460) and its cost of operation was Rs. 640/- per ha. The saving in cost of operation was 88.3% as compared to manual weeding (Rs. 5,470). Time saving with ridge profile power weeder as compared to manual weeding was 93.93%. The ridge profile power weeder had a breakeven point at 179.38 h yr^{-1} with a payback period of 2.74 years.

Introduction

Those plants that interfere with human activity in crop and non-crop areas are considered weeds. Weeds directly affect production through competition for nutrients, light and moisture. Weed competition can reduce crop yields to below economic levels and may render crop virtually unproductive. Weeds have the potential to contaminate and reduce the quality and quantity of produce, act as hosts for insect pests and diseases.

Reduction in yield due to weed alone is estimated to be 16-42% depending upon crop and location, and involves 1/3rd of the cost of cultivation (Rangasamy *et al.*, 1993). Worldwide, 13% loss of agricultural production is attributed to weeds, in spite of the control measures taken by farmers.

If no action were taken to protect crops from weeds, the losses would amount to 30% (Oerke *et al.*, 1994). Mechanical weeding is preferred to chemical weeding because weedicide application is generally expensive, hazardous and selective. Besides, mechanical weeding keeps the soil surface loose by producing soil mulch which results in better aeration and moisture conservation (Duraisamy and Tajuddin, 1999). Generally weeding is done by hand tools, but labour requirement is very high as 300 to 1,200 man-hours per

ha (De Datta *et al*., 1974).

At a conservative estimate, an amount of Rs. 100 billion is annually spent on weed management in India, in arable agriculture alone (Vision 2030, 2011). A recent study undertaken at DWSR suggests that proper weed management technologies, if adapted, can result in an additional income of Rs. 105,036 crores per annum (NRCWS, 2007). Small farm holders spend 50-70% of their total available farm labour on weed control, and is usually carried out by hoe-weeding (Chikoye *et al*., 2002).

Padole (2007) evaluated a rotary power weeder for its field performance in comparison with bullock drawn blade hoe. It worked better than bullock drawn blade in respect of working depth 5.67 cm (16.67% more), effective field capacity 0.14 ha h^{-1} (40% more) and field efficiency 90% (34.11% more). It was more economical and effective than bullock drawn blade hoe as it saved 10.77% weeding cost, reduced plant damage upto 54.23% and achieved weeding efficiency upto 92.76%. Rangaswamy *et al*. (1993) developed and evaluated a power weeder to assess its performance. It was compared with conventional method of manual hand hoe weeding and manually operated dryland weeder. They found that capacity of power weeder was 0.04 ha h^{-1} with weeding efficiency of 93% for removing shallow rooted weeds. The cost of operation with power weeder amounted to Rs. 250/- per ha as against Rs. 490/- per ha by dryland weeders and Rs. 720/- per ha by manual weeding with hand hoe. The saving in cost and time amounted to be 65% and 93%, respectively.

Srinivas *et al*. (2010) compared three comercially available weeders for inter-cultivation in sweet sorghum crop. The weeding efficiency of 'L' shape blade power weeder was found to be 91%, whereas 'C' type and Sweep type blade power weeders recorded 87% and 84%, respectively. Field capacity of Sweep type weeder was 0.12 ha h^{-1}, which was more than 'C' and 'L' type blade weeder and plant damage was minimum as compared to the other two.

Weeding of ridge planted crop mainly done manually and chemical control method. Although, manual weeding is most effective and efficient method of weed control but, it is not practicable in large area. Therefore, in order to bring down cost of cultivation and timeliness of weeding operation ridge profile weeder developed.

Fig. 1 Drawing of ridge profile power weeder developed in Pro-e software; c) Isometric view

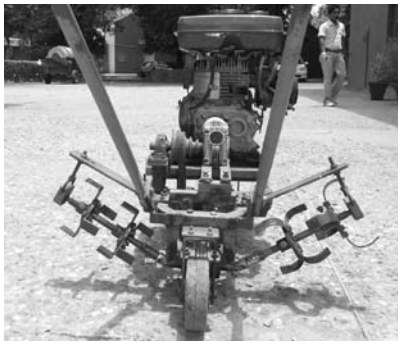
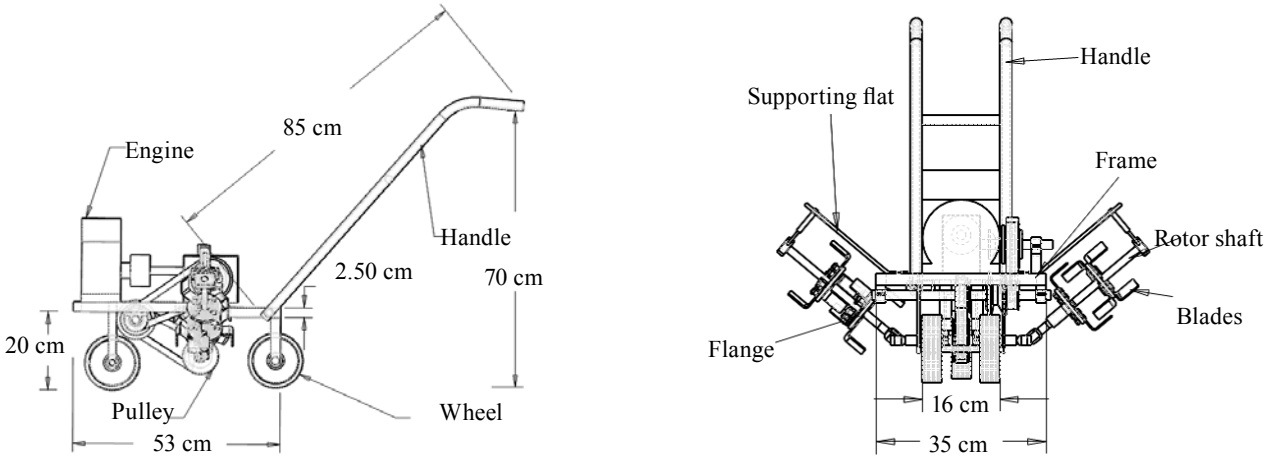


Plate 1 Developed prototype of ridge profile power weeder

Materials and Methods

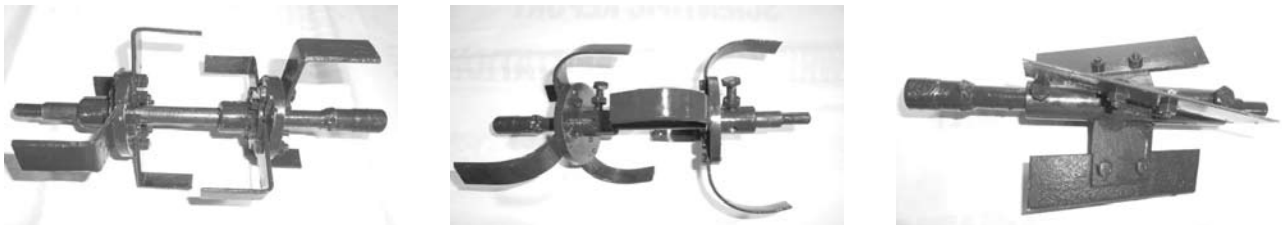
Development of Ridge Profile power Weeder

The prototype was fabricated in the division of Agricultural Engineering, IARI, New Delhi. The research was carried out in potato crop of row-row distance of 600



a) Side view b) Front view

Fig. 1 Drawing of ridge profile power weeder developed in Pro-e software



a) L-type b) C-type c) Flat-type

Plate 2 Different types of cutting blades used for testing

mm and plant to plant distance of 200 mm maintained. The developed ridge profile power weeder consisted of the following components: frame, handle, cutting blades, rotor shaft, belt and pulley, engine and ground wheel. **Fig. 1** is the drawing of the weeder while **Plate 1** is the photograph of the weeder.

Machine Components

Main frame

A main frame of 530 mm length, 200 mm height and 350 mm width was made of M.S. square of size 25 × 25 × 3 mm. The frame had three rubber wheels (140 mm in diameter, 40 mm in width) mounted on a shaft to carry weeder.

Rotor shaft

The maximum tangential force which could be endured by the rotor was considered for design of the rotor shaft. With stress and moment analyses, the diameter of rotor shaft was selected as 18 mm. The length of rotor shaft was 200 mm, so that it could cover inclined surface from top to bottom from one side of ridge.

Power transmission system

The power transmission system consisted of speed reduction unit (ratio = 10: 1), belt and two-step pullies. The power was transmitted from engine to intermediate shaft, and from intermediate shaft to the rotor blade shaft on which cutting blades were mounted.

Cutting blades

Three types of blade were selected viz, L-type, C-type and Flat-type (**Plate 2**). The blades of the rotor was made of mild steel flat of 25 mm width and 6 mm thickness. The radius of the rotor blades was kept as 50 mm. Sixteen blades were fabricated, and four fitted on each flange. Each rotor shaft provided with one pair of flange, and the total cutting width was equal to 200 mm.

Handle

The power weeder was provided with two handles made of 25 mm diameter conduit pipe of 16 gauge and fitted to the frame. Handle height was kept at 700 mm with provision of adjustement as per the convinience of the operator.

Power source

A power source of 2.20 kW, 3,600 rpm, two stroke, petrol-start kerosene-engine was selected. The engine was capable of developing high torque at low speed. Specification of different components of ridge profile power weeder and its material of construction represented in **Table 1**.

Design of Experiment

For conducting experiment, factorial randomised complete block design was adopted. Accordingly, field of size 900 m^2 was divided into 3 equal sized blocks (equal to number of replications) of 30 × 10 m. Within each block, attempt was made to randomise the treatment combination for different levels of variables.

Variables were under study:

- Moisture content (15.28%, 12.23%, 9.33%)
- Types of blade (L-type, C-type, Flat- type)
- Gang speed, rpm (160, 180, 200)

Number of treatments = 3 × 3 × 3 = 27

Number of replications = 3

Total number of observations = 81

Test Procedures

Potato cultivar Kufri Bahar -3797 was raised in the experimental farm of the Division of Agricultural Engineering, IARI, New Delhi as per recommended agronomical practices. In the experimental field total 81 experimental units were selected

Table 1 Specifications of the developed prototype weeder

NO.	Component	Overall dimension	Material of construction
1	Overall Length	1220 mm	25 × 25 × 4 mm
	Width	680 mm	M.S. square section
	Height	700 mm	
2	Soil cutting unit		
	Rotor shaft (2)	Φ = 18 mm, 200 mm	Rolled steel
	Flanges (4)	Φ = 90 mm, 8 mm	M.S
	Cutting blades (16)	25 × 3 mm	M.S. Flat
	Universal joints (2)	Φi = 22 mm	Forged steel
3	Power transmission system		
	No. of step-up pulley	2	Cast iron
	No of V- belt (B- section)	2	Rubber
4	Handle	Φ = 25 mm	G.I pipe
5	Wheels (3)	Φ = 150 mm	M.S
6	Total Weight	53 kg	-

randomly of size 1 × 0.6 m. Weeding was done after 25-30 days of potato planting. Before and after each test run, number of weeds in each experimental unit was counted. With the help of tachometer (Least count = 0.1 rpm) revolution of rotor shaft was measured. The depth of cut was also randomly measured, and the average forward speed was obtained.

Performance Evaluation

Developed prototype of ridge profile power weeder was tested under field conditions in sandy loam soil for its performance in terms of weeding efficiency, plant damage percentage, field capacity and performance index (**Plate 3**).

The following performance indicators were calculated using the observed data in the field:

i) Weeding efficiency

Weeding efficiency is a ratio between the number of weeds removed by a weeder and the number present in a unit area and is expressed in percentage as follows:

$$\text{Weeding efficiency, (\%)} = (W_1 - W_2) / W_1 \times 100 \quad \text{..... (1)}$$

Where,

W_1 = Number of weeds before weeding, and

W_2 = Number of weeds after weeding.

ii) Plant damage

Plant damage (the ratio of the number of plants damaged in a row to the number of plants present in that row) was calculated by the following formula

Plate 3 Field evaluation of Ridge Profile Power Weeder

$$\text{Plant damage, \%} = \{1 - (q/p)\} \times 100 \quad \text{..... (2)}$$

Where,

q = Number of plants in a 10 m row length after weeding, and

p = Number of plants in a 10 m row length before weeding.

iii) Actual field capacity

Actual field capacity (ha.h^{-1}) was computed by recording the area weeded during each trial run in a given time interval. With the help of stopwatch, time was recorded for respective trial run along with area covered.

$$FCa = FCt \times (FE, \%) / 100 \quad \text{..... (3)}$$

Where,

FC_a = Actual field capacity, ha.h^{-1},

FC_t = Theoretical field capacity, ha.h^{-1}, and

FE = Field efficiency, %

iv) Field efficiency

Field efficiency is the ratio between the productivity of a machine under field conditions and the theoretical maximum productivity. It was computed by following formula:

$$\text{Field efficiency} = FC_t / FC_a \times 100 \quad \text{.. ..... (4)}$$

Where,

FC_t = Theoretical field capacity, ha.h^{-1}

FC_a = Actual field capacity, ha.h^{-1}

v) Performance index

Performance index gives idea about overall performance of a particular blade after considering both qualitative and quantitative aspects. The performance index (PI) of weeder could be computed by using following relation:

$$PI = \{FC \times (100 - \text{plant damage}) \times WE\} / P \quad \text{..... (5)}$$

Where,

FC = Field capacity, ha.h^{-1},

PD = Plant damage, %,

WE = Weeding efficiency, % and

P = Power, hp.

vi) Field machine index

For calculating field machine index, total time required to complete one test run and time loss in turning was recorded with the help of stopwatch. The theoretical time required at selected forward speed was calculated. Field machine index was calculated as follows:

$$FMI = (T_p - T_o - T_t) / (T_p - T_o) \times 100 \quad \text{. ..... (6)}$$

Where,

T_p = Total productive time, s,

T_o = Theoretical time, s, and

T_t = Time loss in turning, s.

Cost Economics

The cost of operation of ridge profile power weeder was calculated by taking into account fixed cost and variable cost. It was then compared with cost of manual weeding, and comparative cost saving was determined.

i) Breakeven point

$$BEP = FC / (CH - C) \quad \text{..... (7)}$$

Where,

BEP = Breakeven point, h.yr^{-1},

FC = Annual fixed cost, Rs.yr^{-1},

C = Operating cost, Rs.h^{-1}, and

CH = Custom hiring charges, Rs.h^{-1}, = (C + 25% over head) + 25% profit over new cost

ii) Payback period

$$PBP = IC/ANP \quad \text{..... (8)}$$

Where,

PBP = Payback period, yr,

IC = Initial cost of machine, Rs, and

ANP = Average net annual profit, Rs.yr^{-1},

$$= (CH - C) \times AU$$

$$AU = AA \times EC$$

Where,

AA = Average annual use, h.yr^{-1}, and

EC = Effective capacity of machine, ha.h^{-1}

Results and Discussion

Weeding Efficiency

The average weed population before weeding was 135 per m^2 and after weeding it was 19 weeds per m^2. Weeding efficiency percentage ranged from 74.47 to 93.89% for different soil-machine parameter combinations. Post-hoc analysis of significant variables at 5% level of significance in SPSS software

showed that for maximum weeding efficiency (93.89%), best combination of soil-machine parameters were 15.26±0.96% (d.b) soil moisture content, L-type blade and 200 rpm of rotor shaft (**Fig. 2**).

Plant Damage Percentage

Data showed that plant damage percentage varied from 0.88-7.33% for different soil machine parameter combinations (**Fig. 3**). Post-hoc analysis in SPSS software of significant variable (i.e. blade type) at 5% level of significance showed that C- type blade was most effective and caused least plant damage percentage (0.88%). Lower percentage of plant damage was found in case of C-type blade due to its curvature at the end whereas, it was higher in case of flat-type blade because of its larger projected surface area coming in contact with plant canopy.

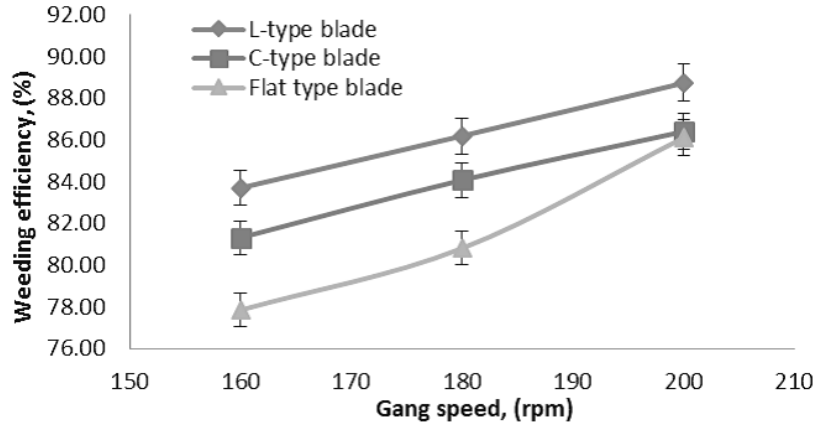


Fig. 2 Influence of blade types and gang speed on weeding efficiency

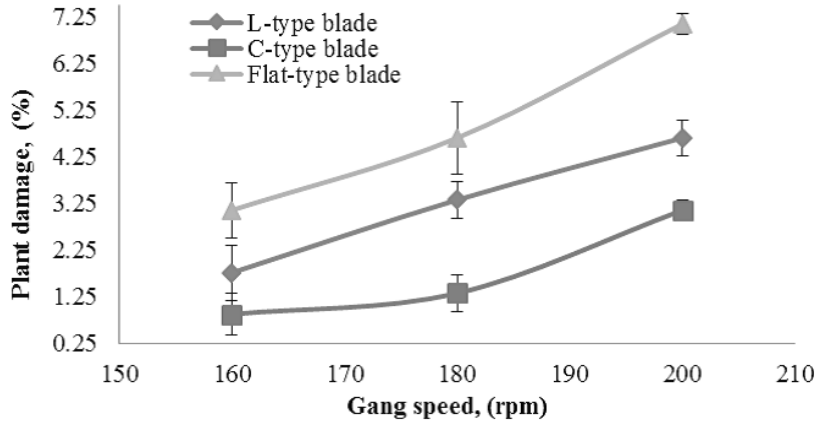


Fig. 3 Influence of blade types and gang speed on plant damage

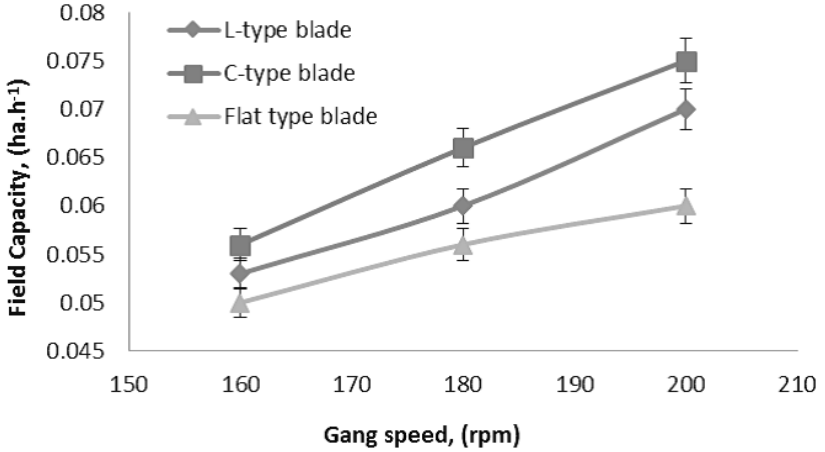


Fig. 4 Influence of blade types and gang speed on actual field capacity

Actual Field Capacity

There were no significant differences in actual field capacity for any soil-machine parameter combinations at 5% level of significance (R^2 = 0.3561). The average value recorded for the actual field capacity was 0.0691 ha.h^{-1} at forward speed ranged between 1.2 to 1.4 km.h^{-1} (**Fig. 4**). However, C-type blade indicated upper values of actual field capacity due to relatively easy cutting of soil in comparison to other two types of blade showing increasing trend for all selected rotor shaft speeds.

Field Efficiency

Field efficiency accounts for failure to utilize the theoretical operating width of the machine; time lost because of operator capability and habits and operating policy; and field characteristics. As weeder was manually operated, theoretical field capacity was calculated by taking average speed of operation 1.3 km.h^{-1} and working width of 0.6 m. Whereas, recorded actual field capacity was 0.069 ha.h^{-1}. Substituting above figures in equations (3) & (4), field efficiency was estimated to 88.5%.

Performance Index

Performance index was estimated for each type of blade by using equation 5. Maximum performance index was found in case of C- type blade as 192.34, while lowest as 153.94 for Flat- type blade (**Fig. 5**).

Field Machine Index

Field machine index for the developed weeder was found to be highest (70.3%) with an average of 66.5% (**Table 2**).

Cost Economics

The cost of operation of the ridge profile power weeder (Rs. 640/- per ha) was much lower than cost of manual weeding (Rs. 5470/- per ha), which saves up to 88.3% operational cost as compared to manual weeding.

Fixed cost of power weeder, $Rs.h^{-1}$ = 14.73

Variable cost of weeder, $Rs.h^{-1}$ = 36.38

Total cost of weeder operation, $Rs.h^{-1}$ = 51.11

Cost of weeder operation, $Rs.ha^{-1}$ = 640

Cost involved in manual weeding, $Rs.ha^{-1}$ = 5470

Cost saving, $Rs.ha^{-1}$ = 4830

Cost saving, % = 88.3%

Break even point, $h.yr^{-1}$ = 179.38

Payback period, yr = 2.74

Conclusions

The ridge profile power weeder, from it field tests, provided a practical means for mechanical weeding particularly for ridge planted crop with accuracy, simplicity and speed with considerably lower labour requirement. The developed weeder performed at a depth and width of operation of 4 mm and 600 mm. The performance index for C-type blade was found as 192.34 which is highest one among all three blades tested. The effective field capacity was 0.066 $ha.hr^{-1}$, which was about 16.5 times that of the manual weeding (manual weeding has taken 250 hrs per ha). Thus, weeder has potential to cope with labour shortage during peak period and reduction in total production cost of crop cultivation. Moreover, It has reduced drudgery to operator as operation performed in standing position otherwise, prevailing squatting position in manual weeding relatively stressful. The Ridge profile power weeder is more appealing to small and marginal farmer as no mechanical aid available other than manual weeding for ridge planted crops. The cost of the weeder was about Rs. 27,600 ($460).

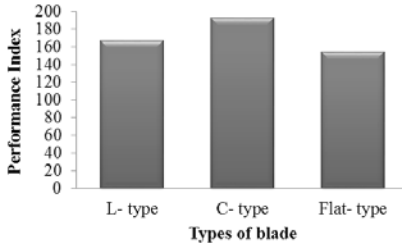


Fig. 5 Performance index for different types of blade

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Table 2 Field machine index for trials conducted during experiment

Total productive time (s)	Theoretical time (s)	Time loss in turning (s)	Machine index (%)
135	90	18	60
148	90	16	70.3
139	90	16	67.35
	Average		65.88

ABSTRACTS

The ABSTRACTS pages is to introduce the abstracts of the article which cannot be published in whole contents owing to the limited publication space and so many contributions to AMA. The readers who wish to know the contents of the article more in detail are kindly requested to contact the authors.

1434

Evaluation of Solar Energy Collected by the Plastic Greenhouses for Drying Agricultural and Industrial Wastes of Banana: Said Elshahat Abdallah, Associate Prof., Dept. of Agril. Eng., Faculty of Agriculture, Kafrelsheikh University, Kafr Elsheikh 33516, EGYPT, saidelshahat@agr.kfs.edu.eg; **Wael Mohamed Elmessery**, Lecturer, same; **A. B. Elnaggar,** Researcher, Agricultural Engineering Research Institute, EGYPT; **A. G. Eldreeny**, M. Sc. Student, Dept. of Agril. Eng., Kafrelsheikh University

Banana is the most waste generating among economic plants in the field due to sequence operations done during production year around. Drying air characteristics; greenhouse solar drier effectiveness; banana tree residues and banana peels distribution way on drying trays are highlighted for drying process optimization. Dried banana wastes introduced for lamb feeding is investigated. Both energy and exergy analyses of the drying process of banana wastes, using three different solar collectors in geometric shape with three independent drying chambers having the same geometric dimensions (mixed-mode forced convection type solar drier), are presented. Banana wastes get sufficiently dried at temperatures between 30°C and 54°C. Throughout the experimental procedure, air relative humidity did not exceed 66%, and solar radiation ranged from 69.34 to 871.6 W/m^2. Drying air mass flow was maintained within the interval of 0.0130 to 0.0143 kg/s. Under these experimental conditions, two days were needed to reduce the moisture content to approximately one-fifteenth of the original value, in particular from 14.153 kgH_2O/kg dry matter down to 0.9 kgH_2O/kg dry matter via Cylindrical solar drier. The Cylindrical solar collector had the highest effect on the drying air capacity which can increase it rapidly decreasing moisture content dramatically in the second day, with the highest drying rate of 0.0302 kg H_2O and drying efficiency of 46.2% for banana wastes with bed depth of 5 cm and chopping length of 3 cm and 32.5% for banana peels with bed depth of 5 cm. Energy utilization ratio for Cylindrical, Quonset and Trapezoidal solar driers was 48.77, 52.06 and 55.58% respectively. The product with chopping length of 3 cm had the highest pick-up efficiency with both bed depths of 5 and 8 cm due to its higher specific surface area. Multiple linear regression analysis was done for studying the regress variables of wastes bed depth, chopping length, specific enthalpy of drying air, drying air capacity, heat energy gained, exergy and moisture content with drying rate and multiple linear regression equations were developed. Implementation of the first law of thermodynamics, energy analysis was carried out to estimate the amounts of heat energy gained from the created solar collectors and the ratio of energy utilization of the drying chamber. Also, applying the second law, exergy analysis was developed to determine the type and magnitude of exergy needed during the solar drying process. It was found that the great amount of exergy losses have been mainly during the second drying day, when the available energy was less used. The summation of exergy required was of 0.36, 0.1423 and 1.5 kJ/kg for the Cylindrical, Quonset and Trapezoidal solar driers during the first drying day, and of 0.94186, 0.44184 and 1.218 kJ/kg respectively during the second drying day.

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1437

TECHNICAL ASSESSMENT OF CATFISH EFFLUENTS MANAGEMENT IN LAGOS STATE, NIGERIA: Omofunmi O. E., Department of Agricultural and Bio-Environmental Engineering, YABATECH, Lagos, NIGERIA, omofunmieric@yahoo.com; **J. K. Adewumi**, Department of Agricultural Engineering, Federal University of Agriculture Abeokuta, same; **A. F. Adisa**, same; **S. O. Alegbeleye**, Department of Fisheries and Aquaculture, same

Catfish production is now becoming a fast growing small-medium scale industry in Nigeria. Fish is and one of major source of dietary protein in Nigeria, and Lagos State in particular, for culturing with abundant freshwater and marine environments. The aim of the study is to evaluate the fish rearing industry and make appropriate recommendations. Forty fish farms were randomly selected in Lagos State. Questionnaire and in-depth interview of fish farmers were used for data collecting covering on water sources, equipment operations, waste management and disposal methods and data were analyzed using descriptive statistics. Water quality parameters such as transparency, suspended solids (SS) and dissolved oxygen were examined in accordance to the APHA (2005) standards. Results indicates that over 80% of water for fish rearing were from shallow well and 95% of the waste water generated were not treated before disposal into streams .The negative effects of untreated waste water contain high organic loading from fish farming on the immediate physic-chemical and biological environment cannot be overemphasis. Effluents managements employed were open pit, 12.5%; drainage canal, 32.5%; bared-land, 10.0%; stream, 22.5% and re-used on farm, 12.5%, only few farmers carried out simple treatment before disposal, infiltration, 2.5% and sedimentation was 2.5%. Nuisance such as odour, smell, and

gases such as H2S, as a result of anaerobic decomposition of organic matter from fish feed, vermin, standing water can also serve as breeding ground for mosquito, and flies and these are worth monitoring for public health concerns.

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1449

Development of Small Scale Solar Water Heating Assisted Paneer Manufacturing System for Rural Milk Producers: Ruchi Sahu, M. Tech. (D.E.) Student, College of Dairy Science and Food Technology, Chhattisgarh Kamdhenu University, Raipur -492 006, Chhattisgarh, INDIA; **A. K. Agrawal**, Dean, College of Dairy Science and Food Technology, same; **S. Karthikeyan**, Professor, College of Dairy Science and Food Technology, same

Paneer is an important acid-coagulated indigenous milk product. Presently heat treatment is given by burning coal or furnace oil (for generation of steam/hot water) which ultimately increases CO_2 or methane component of atmosphere. Solar energy system is unlimited source of energy and it is free of cost because it is naturally occurred. We can use this energy for paneer manufacturing process. The objectives of the present investigation were to develop paneer manufacturing system, to prepare paneer using above system and to assess the sensory quality of paneer. The adopted method involved solar water heating system which was connected to surface heat exchanger, gave temperature of the water in the surface heat exchanger up to 80-85°C. This hot water temperature is used for heating milk for paneer manufacturing. The experimental paneer was compared with control for their chemical, microbial and sensory characteristics. The experimental paneer had 51.73, 24.35, 48.27 and 0.49% moisture, fat, total solid and acidity respectively and was comparable to control. The total and coliform counts were 7.1×10^3 and 77 cfu/g; 6.2×10^3 and 69 respectively for experimental and control paneer samples and was within the BIS microbial standards specified for paneer. The experimental paneer had significantly ($p \leq 0.05$) higher body and texture (32.7 out of 35) scores, while flavour and colour and appearance scores were comparable to control. Solar water heating system assisted surface heat exchanger (an environmental friendly) system was effectively used to produce good quality paneer without using fossil fuel.

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1452

Portable Evaporatively Cooled Storage Chamber for Fruits and Vegetables: Sanjaya K Dash, Professor and Head, Dept. of Agril. Processing and Food Eng, College of Agril. Eng. and Technology, Orissa University of Agriculture and Technology, Bhubaneswar -751003, Odisha, INDIA, sk_dash1006@hotmail.com; **Manoj Kumar Panda**, Associate Prof., same; **Uma Sankar Pal**, same; **Chinmaya Kishore Bakhara**, same

Evaporative cooling has the potential to reduce the temperature and increase the relative humidity (RH) of an enclosed space. Thus, in the absence of refrigerated storage facilities for on-farm situations, where power availability is often a problem, evaporative cooled storage structures can be used to extend the shelf life of perishable commodities. A portable evaporatively cooled (EC) storage chamber (0.5 m³ capacity) was developed for short term storage of fruits and vegetables. The chamber (1.0 × 0.5 × 1.0 m inside dimensions) was constructed with a metallic frame made up of mild steel square iron bars, flats and angles with side walls made up of aspen fibre pad sandwiched between plastic nets. The top of the chamber was covered with a tray made up of GI sheet, which also served as a small water reservoir. The holes along the periphery of the tray allowed the water to trickle down along the side walls and kept them wet. A chimney was installed over the top for improving the ventilation inside the chamber. It was observed that the inside temperature of the chamber remained 1.5-3.5°C higher than the ambient wet bulb temperature. The chimney was heated during peak sunshine hours, which increased the infiltration of saturated air and further increased the cooling effect. The cooling efficiency of the chamber ranged from 83.36 ±0.97 to 85.93±1.69%. The RH within the chamber was 75-85%. The chamber was tested for storage of seed ginger, and it was observed that the physiological loss in weight (PLW) of ginger could be significantly reduced as compared to rustic sand storage methods.

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1454

A Low Cost Manual Seed Drill for Sowing of Jute Seeds: V. B. Shambhu, Senior Scientist, National Institute of Research on Jute & Allied Fibre Technology, 12, Regent Park, Kolkata -700 040, West Bengal, INDIA, vbs9605@gmail.com; vbs9605@yahoo.co.in

Jute is one of the bast fibres and commercially grown as cash crop in the world and the second most important textile fibre next to cotton. Jute plays a significant role in livelihood of the resource poor small and marginal farmers in India. Jute farmers generally follow broadcast method of jute sowing where the placement of seeds at proper soil depth and uniformity cannot be attained. It becomes extremely difficult to place correct quantity of tiny seeds manually at desired depth of soil for optimum plant population due to small size of seeds. On the other hand, line sowing of small seeds like jute, mustard, and sesame etc. is very much desirable to save seed as well as maintaining plant population, reduce cost of sowing, weeding and thinning. Therefore, a simple manually drawn multi-row seed drill for jute as well as small seeds was developed and evaluated in the laboratory and field conditions. It ensures uniform germination and proper crop stand on one hand and facilitates other post sowing operations like weeding and thinning, fertilizer application, plant protection measure, irrigation and harvesting of jute crop on the other hand. The developed drill required only 75.16 N of draft for its operation which was within the capacity of an average man. It was also found that the time required in line sowing for jute was only 6 man hours per hectare which was same as compared to traditional method of sowing.

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1483

Impact of Colored Plastic Mulches on Plant Light Environment, Soil Temperature and Yield of Bell Pepper Under Field Conditions: Sushant Mehan, Dept. of Soil and Water Engineering, Punjab Agril. University, Ludhiana -141004, INDIA; **Rakesh Sharda**, same; **K. G. Singh**, same

A field experiment was conducted in the year 2012-13 to study the effect of colored mulches on soil temperature and yield of bell pepper (*Capsicum annuum* L.) under field conditions. Treatments were replicated three times in a randomized completely- block design and were as follows: Yellow on black, Black on black, Silver on black, White on black and unmulched soil as control. The higher FR: R (Far red: Red) ratios and NDVI values were found in case of black on black and silver on black colored plastic mulch which was responsible for better vegetative growth in case of plots covered with colored plastic mulches as compared to control plot. This resulted in greater absorption of red light in case of darker colored mulches and thus raised temperature of soil under them at 5 cm and 15 cm depth of soil. Both the crop quality and crop quantity enhanced on plots covered with colored plastic mulch sheets. Highest yield of 302.4 q/ha was reported in silver on black colored plastic mulch. So, it is beneficial to grow bell pepper on silver on black colored plastic mulch or black on black for bringing overall improvement in crop by modifying the plant light environment around the crop that results in higher yield and better quality of produce.

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1608

Development of Hybrid Grader for Processing Fruits of Ziziphus sp ('ber'): P. K. Malaviya, ICAR-Central Arid Zone Research Institute, Jodhpur, Rajasthan 342003, INDIA, prabhatald@hotmail.com; **P. Santra**, same; **P. C. Pande**, same

Ziziphus sp (ber) is commercially cultivated in arid zone of India. Fruits of Ziziphus sp are generally graded manually to fetch higher price. When there is seasonal glut it become difficult to grade the fruits manually. Keeping this in mind, a grader was designed and developed to grade harvested fruits into three different sizes: >35 mm, 25-35 mm, and <25 mm. Considering the possibility of operating the grader in field condition where electric supply line is not available, provisions were created in the machine to operate it with stand-alone PV panel generated electricity. Performance studies indicated successful operation of the system in hybrid mode both through electricity and PV generated power with grading capacity of 250-300 kg hr^{-1}. Experiments revealed excellent potential of this novel device in remote rural areas for accruing higher benefits through selling of graded ber.

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EVENT CALENDAR

◆ 51st Annual Convention of Indian Society of Agricultural Engineers (ISAE) and National Symposium
February 16-18, Haryana, INDIA
http://www.isae.in/conventionile/(RJ)%20ISAE%20Brochure%205.pdf

◆ European Intelligent Agriculture Congress
February 16-17, Brussels, BELGIUM
http://www.mnmconferences.com/European-Intelligent-Agriculture-Congress

◆ 1st AXEMA-EurAgEng Conference
February 25, Villepinte, FRANCE
http://www.eurageng.eu/sites/eurageng.eu/files/docs/AXM_Conf%C3%A9rence%20_Announcement_2016-09-28.pdf

◆ SIMA 2017
February 26 - March 2, Villepinte, FRANCE
https://en.simaonline.com/

◆ NATIONAL CONGRESS ― New Challenges and Advances in Sustainable Micro Iriigation ―
March 1-3, Coimbatore, INDIA
http://www.tnauncmi2017.in/

◆ AGRITECHNICA ASIA 2017
March 15-17, BITEC, Bangkok, THAILAND
https://www.agritechnica.com/en/press/?detail/agritechnica2015/10/2/8554

◆ International VDI Conference ― Smart Farming ―
March 28-29, Dusseldorf, GERMANY
https://www.vdi-wissensforum.de/en/event/smart-farming/

◆ 2nd International VDI Conference ― Connected Off-Highway Machines 2017 ―
March 28-29, Dusseldorf, GERMANY
https://www.vdi-wissensforum.de/en/event/connected-off-highway-machines/

◆ CaspianAgro 2017 –11th Azerbaijan International AGRICULTURE EXHIBITION–
May 25-27, Baku, AZERBAIJAN
http://caspianagro.az/2017/?p=index

◆ 20th FOODAGRO Africa 2017
June 2-4, 2017, Nairobi, KENYA
http://www.expogr.com/kenyafood/

◆ XXXVII CIOSTA & CIGR Section V Conference
June 13-15, 2017, Palermo, ITALY
http://www.aidic.it/ciosta2017

◆ 2nd International Forum on Agri-Food Logistics
June 22-23, Poznan, POLAND
http://www.agrifoodlogistics.eu/

◆ ASABE 2017 Annual International Meeting
July 16-19, Spokane, USA
http://www.asabemeetings.org/

◆ AGM & Technical Conference (Joint Meeting with CIGR Section VI Bioprocesses)―FOOD, FUEL, AND FIBRE FOR A SUSTAINABLE FUTURE―
August 6-10, Winnipeg, CANADA
www.csbe-scgab.ca/winnipeg2017

◆ ASIA AGRI-TECH EXPO & FORUM 2017
September 28-30, Taipei, TAIWAN
http://www.agritechtaiwan.com/en-us/

◆ Agritechnica 2017
November 12-18, Hanover, GERMAY
https://www.agritechnica.com/en/

◆ AGROCIENCIAS 2017
November 20-24, Havana, CUBA
Organizer: Agrarian University of Havana

◆ XIX. World Congress of CIGR
April 22-25, 2018, Antalya, TURKEY
http://www.cigr2018.org/

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Communiqué of the Conference on Agricultural Mechanization in Nigeria

Organized by the Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

August 1-4, 2016 at the University's Anyim Pius Anyim Auditorium

Introduction

A conference on Agricultural Mechanization in Nigeria was held at Michael Okpara University of Agriculture, Umudike, Abia state, Nigeria which was organized by the Institute's Department of Agricultural and Bioresources Engineering, College of Engineering and Engineering Technology. The conference was held at the University's Anyim Pius Anyim Auditorium from 1st to 4th August, 2016.

The main objective of the conference was to bring stakeholders in the agriculture industry together to examine issues of agricultural mechanization in Nigeria. The theme of the conference was "Mechanization of Root and Tuber Production and Processing in Nigeria''. A total of 197 participants attended the conference comprising of engineers, legislators, farmers, agronomists, scientists, economists, academics, women groups and other professionals and students from different sectors notably universities, polytechnics, ministries, private sector, research institutes, farming, the legislature, etc.

Four Lead papers were presented at the plenary session. The Lead papers presented focused extensively in the field of agriculture, engineering and allied professions. The topics of the four Lead papers presented were as follows:

1. "Prospects for Mechanizing Root and Tuber Production and Processing in Nigeria" which was presented by Engr. A. G. Abubakar, Deputy Director, Engineering and Mechanization, Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria.
2. "Developments in Machineries for Mechanizing Root and Tuber Production and Processing Operations in Nigeria" which was presented by Engr. Dr. Muyideen Kasali, Ag. Executive Director, National Centre for Agricultural Mechanization (NCAM), Ilorin, Kwara State, Nigeria.
3. "Examination of Tractor Hiring Programme for Effective Mechanization of Root and Tuber Crops Production in Nigeria" which was presented by Engr. Bitrus Yakubu Elesa, Retired Director Mechanization, Federal Ministry of Agriculture and Rural Development, Abuja and National President, Tractor Owners and Operators Association of Nigeria.
4. "Overview of the Root and Tuber Expansion Programmes in Nigeria" which was presented by Dr. C. O. Amadi, Assistant Director, Ginger Programme, National Root Crop Research Institute (NRCRI), Umudike, Abia State, Nigeria.

The keynote Address presented during the conference focused on the mission of agricultural engineering, importance of agricultural mechanization for the enhancement of root and tuber production and processing in Nigeria, the reasons for encouraging production and processing of root and tuber crops in Nigeria, etc. At the technical sessions of the conference, several papers were presented which were discussed under the fields of engineering and agriculture. Some of these fields include power, machinery, soil, water, aquaculture, bio-process, food engineering, mechanization, policy, etc.

Key Observations

At the end of the conference, the following key observations were made:

1. The colonial agricultural production operation was characterized by the use of cutlass and hoe for the production of cash crops only.
2. The post independence agricultural production operation experienced mechanization and so many Nigerians mostly the youths were involved in agriculture.
3. Agriculture then was the major employer and source of income for the government, companies and individuals.
4. Governments of Nigeria, past and present, have good policies and programmes for agricultural development.
5. Mechanization inputs from the National Centre for Agricultural Mechanization (NCAM), Ilorin and the defunct National Agricultural Land Development Authority (NALDA) are almost absent in all policies and programmes of agricultural development in Nigeria.
6. Agricultural production and processing operations in Nigeria have remained at the first and most basic level where over eighty percent of the operations were carried out using human labour.
7. The drudgery associated with hand powered agricultural production and processing operations is the major reason that made the youths to abandon agriculture in search of white collar job.
8. Increase in population has resulted in increased demand for food. The lack of job opportunities, reduced revenue from oil and the crude nature of hand powered agriculture are some of the factors that call for shift to agricultural mechanization.
9. The National Centre for Agricultural Mechanization (NCAM), Ilorin has developed series of machineries for root

and tuber production and processing in Nigeria.

10. The number of tractors and the associated implements in Nigeria are grossly inadequate.
11. Nigeria is under mechanized.
12. There is no policy on Agricultural Mechanization in Nigeria.
13. The Nigerian agricultural sector is suffering from unreliable and inconsistent transport, storage marketing and pricing policies.
14. The most viable option to the diversification of the Nigerian economy is to mechanize the Nigerian agricultural production and processing systems.
15. The Nigerian Institution of Agricultural Engineers (NIAE) is a major stakeholder in agricultural mechanization issues in Nigeria.
16. The Agricultural Equipment Hiring Enterprise being operated by the Federal Ministry of Agriculture and Rural Development is attempting to address the problems of tractor and equipment services in the country.
17. The increase in the number of tractor breakdowns in Nigeria resulting from the lack of tractor spare parts is traceable to the attitude of State Government officials importing various makes and models of tractors without any regulation.

Recommendations

The following recommendations emanated from the conference:

1. The Federal Government should formulate a national policy on agricultural mechanization in Nigeria. The document will serve as a guide to government and other stakeholders on matters related to agricultural development in Nigeria.
2. The National Centre for Agricultural Mechanization (NCAM), Ilorin, should be encouraged to improve on existing design and development of machineries for the production and processing of root and tuber crops.
3. Agricultural Mechanization should be an integral part of the National Policy on Rural Development.
4. The Nigerian Institution of Agricultural Engineers (NIAE) and the Departments of Agricultural and Bioresources/Biosystems/Environmental Engineering in Universities, Colleges of Agriculture and Polytechnics in the country should be challenged and supported to provide technical and advisory services to the government on issues related to agricultural mechanization in Nigeria.
5. The Agricultural Equipment Hiring Enterprise being operated by the Federal Ministry of Agriculture and Rural Development should be sustained and expanded.
6. Mechanized agricultural land development is a welcome addition to the previous efforts towards enhanced food production and efforts must be made to identify and solve any form of obstacles to its success. To this end, the scrapping of the National Agricultural Land Development Authority should be revisited.
7. Governments should encourage increased production and processing of root and tuber crops in Nigeria.
8. The Federal Government of Nigeria should enforce importers of agricultural machinery and equipment to conduct tractor and equipment test usually done by the National Centre for Agricultural Mechanization (NCAM) before releasing these tractors and equipment to the public for use.

Chairman, Local Organizing Committee: Engr. Dr. Joseph C. Adama

Secretary, Local Organizing Committee: Engr. James Ehiem

Chairman, Communiqué Drafting Committee: Engr. Prof. V. I. O. Ndirika

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Co-operating Editors


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A H Abdoun


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-AFRICA-

Benedict Kayombo
Assoc. Prof. of Soil and Water Eng., Dept. of Agric. Eng. and Land Planning, Botswana College of Agric., Univ. of Botswana, Private Bag 0027, Gaborone, BOTSWANA. TEL+267-3650125, bkayombo@bca.bw

Mathias Fru Fonteh
Assoc. Prof. and Head, Dept. of Agril. Eng., Faculty of Agronomy and Agril. Sciences, Univ. of Dschang, P.O. Box 447, Dschang, West Region, CAMEROON. TEL+237-7774-0863, matfonteh@yahoo.com

Said Elshahat Abdallah
Assoc. Prof. of Agril. & Biological Process Eng., Dept. of Agril. Eng., Faculty of Agric., Kafrelsheikh Univ., Kafr Elsheikh 33516, EGYPT. TEL+20-473-14-8949, saidelshahat@agr.kfs.edu.eg

Ahmed Abdel Khalek El Behery
Agric Eng. Research Institute, Agril. Research Center, Nadi El-Said St. P.O. Box 256, Dokki 12311, Giza, EGYPT. behery28@yahoo.com

Ahmad Addo
Assoc. Prof., Department of Agril. Engg, Kwame Nkrumah Univ. of Sci. and Tech. (KNUST) Kumasi, GHANA. TEL+233-3220-60242, aaddo.coe@knust.edu.gh

Richard Jinks Bani
Lecturer & Co-ordinator, Agric. Eng. Div., Faculty of Agric., Univ. of Ghana, Legon, GHANA

Israel Kofi Djokoto
Prof., Israel Kofi Djokoto, Associate Prof. Univ. of Science and Technology, P.O.Box 420 ust, Kumasi, GHANA, profdjokoto@yahoo.com

AYUB N. GITAU
Chairman and Associate Prof., Dept. of Environmental and Biosystems Engineering, University of Nairobi, P.O Box 30197, Nairobi, KENYA, ayub.gitau@uonbi.ac.ke; gitauan@yahoo.co.uk

David Kimutaiarap Some
Eng. Prof. Dept. of Agril & Biosystems Eng., School of Engg Chepkoilel University College of Moi Univ., P.O. Box: 2405-30100, Eldoret, KENYA, dkimutaisome2@gmail.com

Karim Houmy
Dr., International Consultant on Agricultural Mechanization, 2 Rue Ali Al Haddani, Route Akrach, Souissi, Rabat, MOROCCO. TEL+212-7-680512, houmy@maghrebnet.net.ma

O. A. Oyelade
Obtaining Doctor, Farm Power and Machinery Dept., National Centre for Agril. Mechanization (NCAM), P.M.B. 1525, Ilorin, Kwara State, NIGERIA. TEL+2348069030588, yemibamigbedjdoyelade@gmail.com

Umar Buba Bindir
Director General/CEO, National Office for Technology Acquisition and Promotion, No 4. Blantyre Street, Wuse II PMB 5074, Abuja, FCT Federal Republic of NIGERIA. TEL+234-9461-1183, ubindir@yahoo.com

Joseph Chukwugotium Igbeka
Prof., Dept. of Agril. Eng., Univ. of Ibadan,, Ibadan, NIGERIA. TEL+234-2-810-1100-4, Library@Ibadan.ac.ng

Emmanuel Uche Odigboh
Prof., Agril. Engg Dept., Faculty of Eng., Univ. of Nigeria, Nsukka, Enugu state, NIGERIA. TEL+234-042-771676, MISUNN@aol.com

Kayode C. Oni
Dept. of Agril. & Biosystems Eng., Faculty of Eng. & Technology, Univ. of Ilorin, PMB 1515, Ilorin, NIGERIA. TEL+234-803-5724708, kayoroll@gmail.com

Umezuruike L. Opara
Research Prof., S. Africa Research Chair in Postharvest Technology, Faculty of AgriSciences, Stellenbosch Univ., Private Bag X1, Stellenbosch 7602, SOUTH AFRICA. TEL+27-21-808-4604, opara@sun.ac.za

Nathaniel Gbahama Kuyembeh
Assoc. Prof., Njala Univ. Colle, Univ. of Sierra Leone, Private Mail Bag, Free Town, SIERRA LEONE. TEL+249-11-778620/780045

Abdien Hassan Abdoun
Member of Board, Amin Enterprises Ltd., P.O. Box 1333, Khartoum, SUDAN.

Amir Bakheit Saeed
Assoc. Prof., Dept. of Agric. Eng., Faculty of Agric., Univ. of Khartoum, 310131 Shambat, SUDAN. TEL+249-11-310131, absaeed5@yahoo.com

Abdisalam I. Khatibu
P. O. Box 2138, Zanzibar, TANZANIA. khatibu@zansec.com

Solomon Tembo
52 Goodrington Drive, PO Mabelreign, Sunridge, Harare, ZIMBABWE.

-AMERICAS-

Hugo Alfredo Cetrangolo
Full Prof. and Director of Food and Agribusiness Program Agronomy College Buenos Aires Univ., Av. San Martin4453, (1417) Capital Federal, ARGENTINA. TEL+54-11-4524-8041/93, cetrango@agro.uba.ar

Irenilza de Alencar Nääs
Prof., Agril. Eng. College, UNICAMP, Agril. Construction Dept.,P.O. Box 6011, 13081 -Campinas-S.P.,BRAZIL. TEL+55-19-788-1039, irenilza@agr.unicamp.br

Abdelkader E. Ghaly
Prof., Emeritus of Biological & Environmental Eng. Dalhousie Univ., P.O. Box 1500, 1360 Barrington St., Halifax, Nova Scotia, B3H 4R2, CANADA. Abdel.Ghaly@Dal.Ca

Edmundo J. Hetz
Prof., Dept. of Agric. Eng. Univ. of Concepcion, Av. V. Mendez 595, P.O. Box 537, Chillan, CHILE. TEL+56-42-216333, ehetz@udec.cl

Marco A. L. Roudergue
Mechanization and Energy Dept., Agril. Eng. Faculty, Campus Chillan, Univ. of Concepcion, Chile. Vicente Mendez #595, CHILE. TEL+56-42-2208709, malopez@udec.cl

Roberto Aguirre
Assoc. Prof., National Univ. of Colombia, A.A. 237,


S Tembo


H A Cetrangolo


I de A Nääs


A E Ghaly


E J Hetz


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Li Shujun


S M Ilyas


Surya Nath


Indra Mani


C R Mehta


A M Michael


B S Pathak


V M Salokhe


G Singh

Palmira, COLOMBIA. TEL+57-572-271-7000, ra@palmira.unal.edu.co

Omar Ulloa-Torres
Prof., Escuela de Agricultura de la Region, Tropical Humeda(EARTH), Apdo. 4442- 1000, San Jose, COSTA RICA. TEL+506-255-2000, o-ulloa@ns.earth.ac.cr

Yanoy Morejón Mesa
Agril. Engineer Univ. Agraria de La Habana, Facultad de Ciencias Técnicas Autopista Nacional y Carretera de Tapaste Apartado, 18-19 San José de las Lajas, Mayabeque, CP 32700 CUBA. ymm@unah.edu.cu

Pedro Paneque Rondon
Assoc. Prof., Universidad Agraria de La Habana, Facultad de Ciencias Técnicas, Autopista Nacional y Carretera de Tapaste, Apartado 18-19, San José de las Lajas, Mayabeque, CP 32700 CUBA. paneque@unah.edu.cu

S. G. Campos Magaña
PhD. and Prof., Paseo de los Claveles #398, Colonia Parques de la Cañada. CP 25080, Saltillo, Coahuila, MEXICO. camposg_1999@yahoo.com

Hipolito Ortiz-Laurel
Head of Agric. Eng. and Mechanization Dept./ Postgraduate College, Iturbide 73, Salinas de Hgo, S.L.P., C.P. 78600, MEXICO. TEL+52-496-30448.

Ganesh C. Bora
Associate Prof., Dept. of Agricultural and Biological Engineering, Mississippi State Univ., 130 Creelman St., Room 242, P.O. Box 9632, MS 39762, U.S.A. gcbora@abe.msstate.edu

William J. Chancellor
Prof. Emeritus, Bio. and Agr. Eng. Dept., Univ. of California, Davis, CA, 95616, U.S.A. TEL+1-530-753-4292, wjchancellor@ucdavis.edu

Megh R. Goyal
Senior Acquisitions Editor, Agric. & Biomedical Eng. and Retired Professor in Agric. & Biomedical Eng. Univ. of Puerto Rico, Mayaguez P.O. BOX 86, Rincon, PR-00677, U.S.A. m_goyal@ece.uprm.edu

Ajit K. Mahapatra
Agric. & Biosystems Eng. Dept., South Dakota State Univ., P.O. Box 2120 Brookings, SD 57007-1496, U.S.A. TEL+1-605-688-5291, mahapata@sdstate.edu

-ASIA and OCEANIA-

Shah M. Farouk
Prof. (Retd.), Farm Power & Machinery Dept., Bangladesh Agril. Univ., Mymensingh 2202, BANGLADESH. TEL+880-1711-801923, smf1941@yahoo.com

Daulat Hussain
Dean, Faculty of Agric. Eng. and Technology, Bangladesh Agril. Univ., Mymensingh-2202, BANGLADESH. TEL+880-91-52245

Mohammed A. Mazed
Member-Director, Bangladesh Agri. Res. Council, Farmgate, Dhaka, BANGLADESH. mamazed@barcbgd.org

Chetem Wangchen
Programme Director Agril. Machinery Centre Ministry of Agric. Royal Government of Bhutan, Bondey Paro Bhutan 1228, BHUTAN. krtamc@druknet.bt

Mohammad Ali Basunia
Associate Prof., Mechanical Engineering Programme, Institute Teknologi Brunei (ITB), Jalan Tungku Link, Gadong BE 1410, BRUNEI DARUSSALAM, ali.basunia@itb.edu.bn

Li Shujun
Prof., China National Machinery Industry Corporation, No. 3 Danling Street, Haidian District P.C. 100080, CHINA. lishujun@sinomach.com.cn

S. M. Ilyas
Prof. Green View Apartment, Flat-699; Pocket-2; Sector-19; Dwarka, NEW DELHI-110 075, INDIA. Tel+91-11-2804 3612, smilyas15@gmail.com

Surya Nath
c/o R.K. Univ., School of Eng. Rajkot-Bharnagar Highway, KASTURBADHAM, RAJKOT,360020, Gujrat, INDIA. drnath.surya@gmail.com

Indra Mani
Prof., Head of Division of Agril. Eng. IARI, New Delhi-110012, INDIA. maniindra99@gmail.com

C. R. Mehta
Project Coordinator, AICRP on Farm Implements and Machinery, ICAR - Central Institute of Agricultural Engineering, Nabi-bagh, Berasia Road, Bhopal - 462 038, INDIA. crmehta65@yahoo.co.in

A. M. Michael
1/64, Vattekunnam, Methanam Road, Edappally North P.O., Cochin, 682024, Kerala State, INDIA. kmichael65@eth.net

B. S. Pathak
Adjunct Prof., Indian Agril. Research Institute, KC5, Kavi Nagar, Ghaziabad- 201002, INDIA. bspathakprof@gmail.com

Vilas M. Salokhe
Prof., Flat B-1, Royal Gateway Apartment Near Yallama Temple, Main Road Kasaba Bawada Kolhapur - 416006, INDIA. vsalokhe@yahoo.com

Gajendra Singh
Adjunct Professor, Indian Agricultural Research Institute (IARI), 86-C, Millennium Apartments, Sector-61, NOIDA, U. P. 201301, INDIA. TEL+91-99-71087591, prof.gsingh@gmail.com

S. R. Verma
Ex-Dean & Prof. of Agr. Eng., H. No. 14, Good Friends Colony, Barewal Road, Ludhiana 141012. Punjab, INDIA. TEL+91-161-2551096, srverma10@yahoo.com

Kamaruddin Abdullah
The Graduate School/Renewable Energy, Darma Persada University, Jl. Radin Inten II, Pondok Kelapa, East Jakarta, 13450, INDONESIA. TEL+64-21-8649051, kabdullah0997@yahoo.com

Mansoor Behroozi-Lar
Prof., Emeritus Tehran Uni. Agr. Eng., Ph. D., Jalal All Ahmad Nasim St. Nasim Danesh Complex Block #35, second floor Tehran, IRAN. Behroozil@Yahoo.com

Saeid Minaei
Assoc. Prof., Dept. of Agr. Machinery Eng., Tarbiat Modarres Univ., P.O.Box 14115-336, Tehran, IRAN. TEL+9821-44180537, minaee@modares.ac.ir

Ali Mazin Abdul-Munaim
Assistant Prof., Dept. of Agril. Machines and Equipments, College of Agric., Univ. of Baghdad, IRAQ. TEL+964-778-4561, old2a3y@yahoo.com

Kunihiro Tokida
Prof., College of Bio-resource Sciences, Nihon Univ., 1866 Kameino, Fujisawa, 252-0880 JAPAN. TEL+81-466-84-3419, tokida.kunihiro@nihon-u.ac.jp

Bassam A. Snobar
Prof., Univ. of Jordan, Faculty of Agriculture, Am-


S R Verma


Kamaruddin Abdullah


M Behroozi-Lar


Saeid Minaei


A M Abdul-Munaim


K Tokida


B A Snobar


J H Chung


In-Bok Lee


M Z Bardaie


Enkhbayar Gonchigdorj


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Alamgir A Khan


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R P Venturina


S A Al-Suhaibani


A M S Al-Amri


S G Illangantileke


S F Chang


Suming Chen


S Krishnasreni


S Phong-supasamit


A Senanarong


P Soni


C Ertekin


I Haffar

man 11492, JORDAN. snobar@ju.edu.jo

Jong Hoon Chung
Prof., Dept. of Biosystems & Biomaterials Science and Eng., College of Agril. and Life Sciences, Seoul National Univ., Bldg 200 Rm 2216 1 Gwanangno, Gwanak-Gu, Seoul, 151-742, KOREA. TEL+82-2-880-4601, jchung@snu.ac.kr

In-Bok Lee
Prof., Laboratory of Aero-Environmental & Energy Engineering (A3EL), Dept. of Rural Systems Eng., College of Agril. & Life Sciences, Seoul National Univ., San 56-1, Shillim-dong, Gwanak-gu, Seoul-city, KOREA. TEL+82-2-880-4586, iblee@snu.ac.kr

Muhamad Zohadie Bardaie
Prof., Dept. of Agril. and Biosystems Eng., Univ. Putra Malaysia, 43400 upm, Serdang, Selangor, MALAYSIA. TEL+60-3-8946-6410

Enkhbayar Gonchigdorj
Director, School of Eng. & Technology, Mongolian University of Life Sciences, Ulaanbaatar, Zaisan, 17024, MONGOLIA. TEL+60-976-11-341554 enkhbayar@muls.edu.mn

Madan P. Pariyar
Consultant, Rural Development through Selfhelp Promotion Lamjung Project, German Technical Cooperation. P.O. Box 1457, Kathmandu, NEPAL.

Hemanatha P. W. Jayasuriya
College of Agril. and Marine Sciences, P.O. Box 34, PC 123Al-khod, Muscat Sultanate, OMAN. TEL+968-2414-1223, hemjay@squ.edu.om

Alamgir A. Khan
Research Engineer, Agricultural Mechanization Research Institute, Multan, PAKISTAN. alamgirakhtar@hotmail.com

A. Q. A. Mughal
Research Professor, Greenwich Univ., DK-10, Street 38t, Darakshan, DHA Phase-6, Karachi-75500, PAKISTAN. dr.aqmughal@greenwich.edu.pk

Muhammad Saffar Mirjat
Dean, Faculty of Agril. Eng., Sindh Agriculture Univ. Tandojam, PAKISTAN. TEL+92-221653160, drmirjat@hotmail.com

Nawaf A. Abu-Khalaf
Assistant Prof., Palestine Technical Univ. -Kadoorie (PTUK), P.O.Box 405, Hebron, West Bank, PALESTINE. TEL+972-2-2227-846/7, nawafu@hotmail.com

Reynaldo M. Lantin
Retired Professor, College of Engineering and Agro-Industrial Technology, University of the Philippines Los Banos, College, Laguna 4031, PHILIPPINES. TEL+63-49-536-2792, reylantin@gmail.com

Ricardo P. Venturina
PHILIPPINES.

Saleh Abdulrahman Al-suhaibani
Prof., Agril. Eng. Dept.,College of Agric., King Saud Univ., P.O. Box 2460 Riyadh 11451, SAUDI ARABIA. salsuhaibani@gmail.com

Ali Mufarreh Saleh Al-Amri
Prof., Dept. of Agril. Systems Eng., College of Agril. Sciences & Food, King Faisal Univ., P.O.Box 55035, Al-Ahsa, 31982 SAUDI ARABIA. aamri@kfu.edu.sa

Sarath G. Illangantileke
Prof., Sarath Ilangantileke, Consultant in Agric Engineering, Mechanization and Education, 4/567 Victoria Range Bungalows, Kengalla, SRI LANKA. sageilan@gmail.com

Sen-Fuh Chang
Adjunct Prof., Dept. of Bio-Industrial Mechatronics Eng., National Taiwan Univ., 136 choushan Road, Taipei, 106. TAIWAN. sfchang@ntu.edu.tw.

Suming Chen
Prof., Dept. of Bio-Industrial Mechatronics Eng., National Taiwan Univ., 1, Section 4, Roosevelt Road, Taipei, TAIWAN. TEL+886-2-33665350, schen@ntu.edu.tw

Suraweth Krishnasreni
Emeritus Prof. 24/77 Baan Kasemsan 1, Soi Kasemsan 1 Rama 1 Rd., Wangmai, Pathumwan, Bangkok 10330, THAILA, surawethk@gmail.com

Surin Phongsupasamit
President, Institute for Promotion of Teaching Science and Technology, 924 Sukumit Rd. Klong Toey Bangkok, THAILAND, surin1950@hotmail.com

Akkapol Senanarong
Agricultural Engineering Research Institue Department of Agriculture, 50 Phaholyothin Rd., Jatuchak Bangkok 10900, THAILAND, akkapol@ksc.th.com

Peeyush Soni
Associate Professor & Coordinator, Agril. Systems and Eng., School of Environment, Resources and Development; Asian Institute of Technology; 12120 THAILAND, soni.ait@gmail.com

Can Ertekin
Prof., Dpt. of Farm Machinery and Technologies Eng., Faculty of Agril., Akdeniz University, 07070, Antalya, TURKEY. ertekin@akdeniz.edu.tr

Imad Haffar
Managing Director, Palm Water Jumeirah Village (SIte Office Gate #10) Al Khail Road, P.O. Box 215122, Dubai, U.A.E. Tel+971-4-375-1196, imad.haffar@palmwater.ae

Nguyen Hay
Prof., President of Nong Lam Univ., Linh Trung Ward, Thu Duc District, Ho Chi Minh City, VIET NAM. nguyenhay@gmail.com

Pham Van Lang
VIET NAM. langvcd@yahoo.com

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N Hay


P V Lang


T H Katardjiev


P Kic


J Müller


E Gasparetto


W B Hoogmoed


Jan Pawlak


O S Marchenko


M Martinov


J Ortiz-Cañavate


Brian G Sims

-EUROPE-

Tihomir Hristov Katardjiev
General Manager at Yogurtson Trade Ltd., Omachi 216-74, Ichikawa-shi, Chiba-ken 272-0801, Japan (BULGARIA). miro@yogurtson.com

Pavel Kic
Professor, Czech Univ. of Life Sciences Prague, Faculty of Eng. 16521 Prague 6-Suchdol, CZECH REPUBLIC. TEL+420-2-2438314 kic@tf.czu.cz

Joachim Müller
Prof. of the Univ. Hohenheim, Institute of Agril. Eng., Head of Agric.l Eng. in the Tropics and Subtropics, Univ. of Hohenheim, 70593 Stuttgart, GERMANY. TEL+49-711-459-22490, Joachim.mueller@uni-hohenheim.de

Ettore Gasparetto
Former Professor of Agril. Mechanization, Dept. Agril. Eng., Univ. of Milano, Via Galileo Galilei 17, I-35121 Padova, ITALY. TEL+39-0250316619, ettore.gasparetto@unimi.it

W. B. Hoogmoed
Univ. Lecturer, Wageningen Univ., Farm Technology Group, P.O.Box 317, 6708 AA Wageningen NETHERLAND. willem.hoogmoed@wur.nl

Jan Pawlak
Institute for Technology and Life Sciences, Branch in Warsaw, Poland, ul. Rakowiecka 32, 02-532 Warsaw, POLAND. j.pawlak@itp.edu.pl

Oleg S. Marchenko
Prof. and Agril. Engineer, Dept. Head in All-Russia Research Institute for Mechanization in Agric. (VIM), 1st Institutsky proezd, 5, Moscow 109428, RUSSIA. TEL+7-926-492-1207, oleg072000@mail.ru

Milan Martinov
Prof., Faculty of Technical Sciences, Chair for Biosystems Eng., Novi Sad, SERBIA. TEL+ 381-21-485-2369, MilanMartinov@uns.ac.rs

Jaime Ortiz-Cañavate Puig-Mauri
Dpto. Ingenieria Rural Universidad Politécnica de Madrid, Esc. T. S. Ing. Agrónomos 28040-Madrid SPAIN. TEL+34-91-336-5852, jaime.ortizcanavate@upm.es

Brian G. Sims
FAO Agricultural Mechanization Consultant. 3 Bourneside Bedford MK41 7EG, U.K. BrianGSims@aol.com

Retirement Co-editors' Name List

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g. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
h. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
j. Convert national currencies **in US dollars** and use the later consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
l. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..."instead of 45 workers..., or, 5 tractors.

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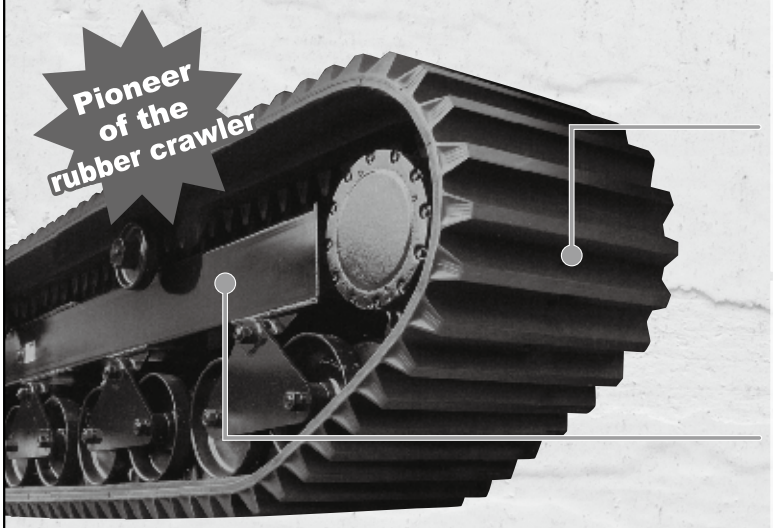
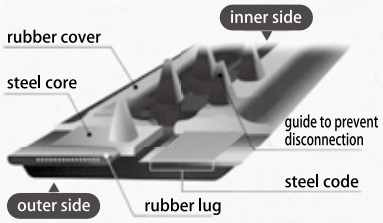


RUBBER CRAWLER

Inner system of rubber crawler



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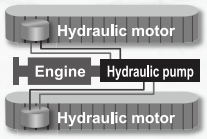

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358, Shoubeeshindenmachi, Ryugasaki city, Ibaraki Prefecture, 301-0031, Japan
TEL. +81-297-66-2111 FAX. +81-297-66-3110 E-mail. info@morooka.co.jp
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